Assessing opportunities to increase global food production within the safe operating space for human freshwater use

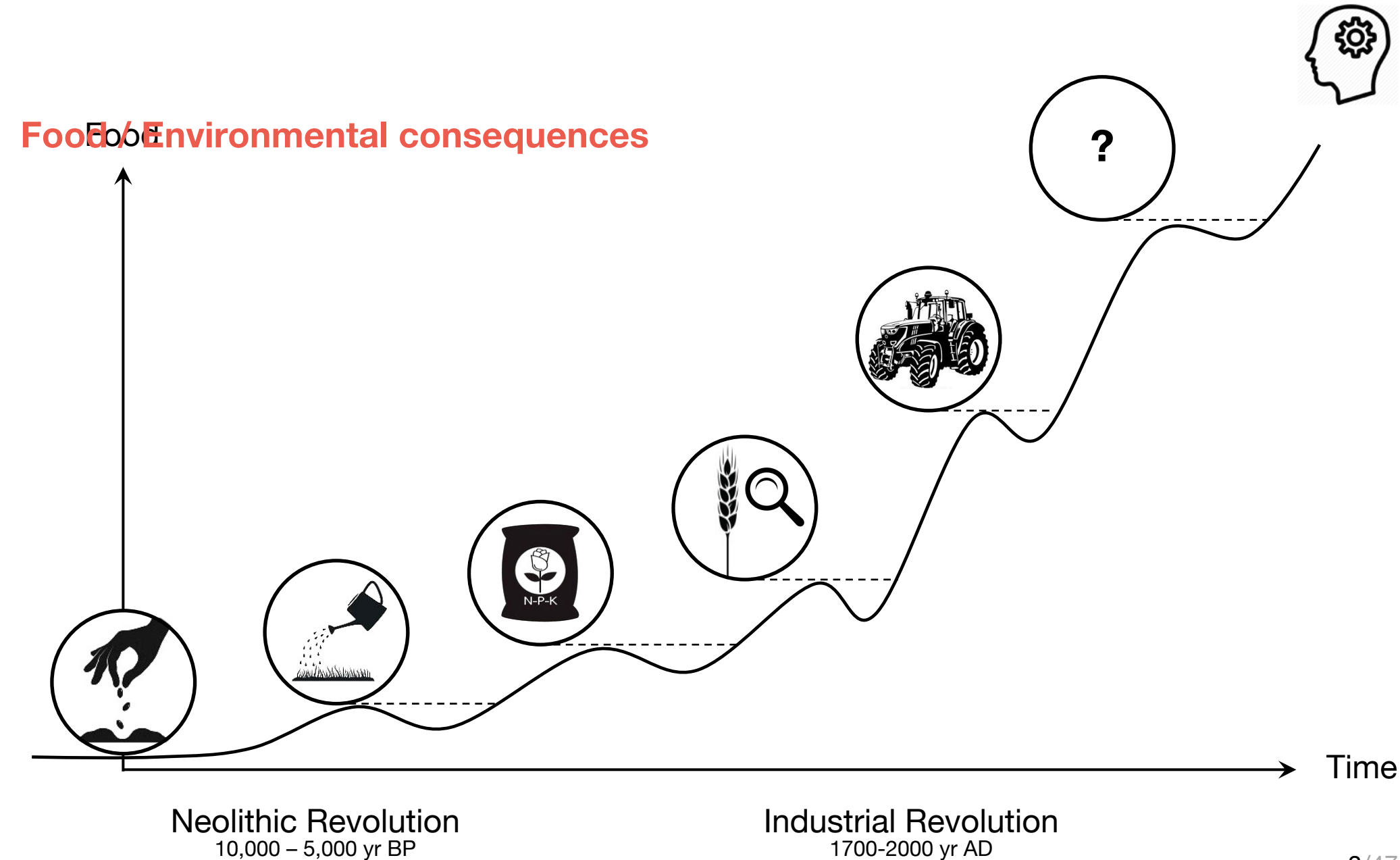
Jonas Jägermeyr, PhD

NASA GISS lunch seminar

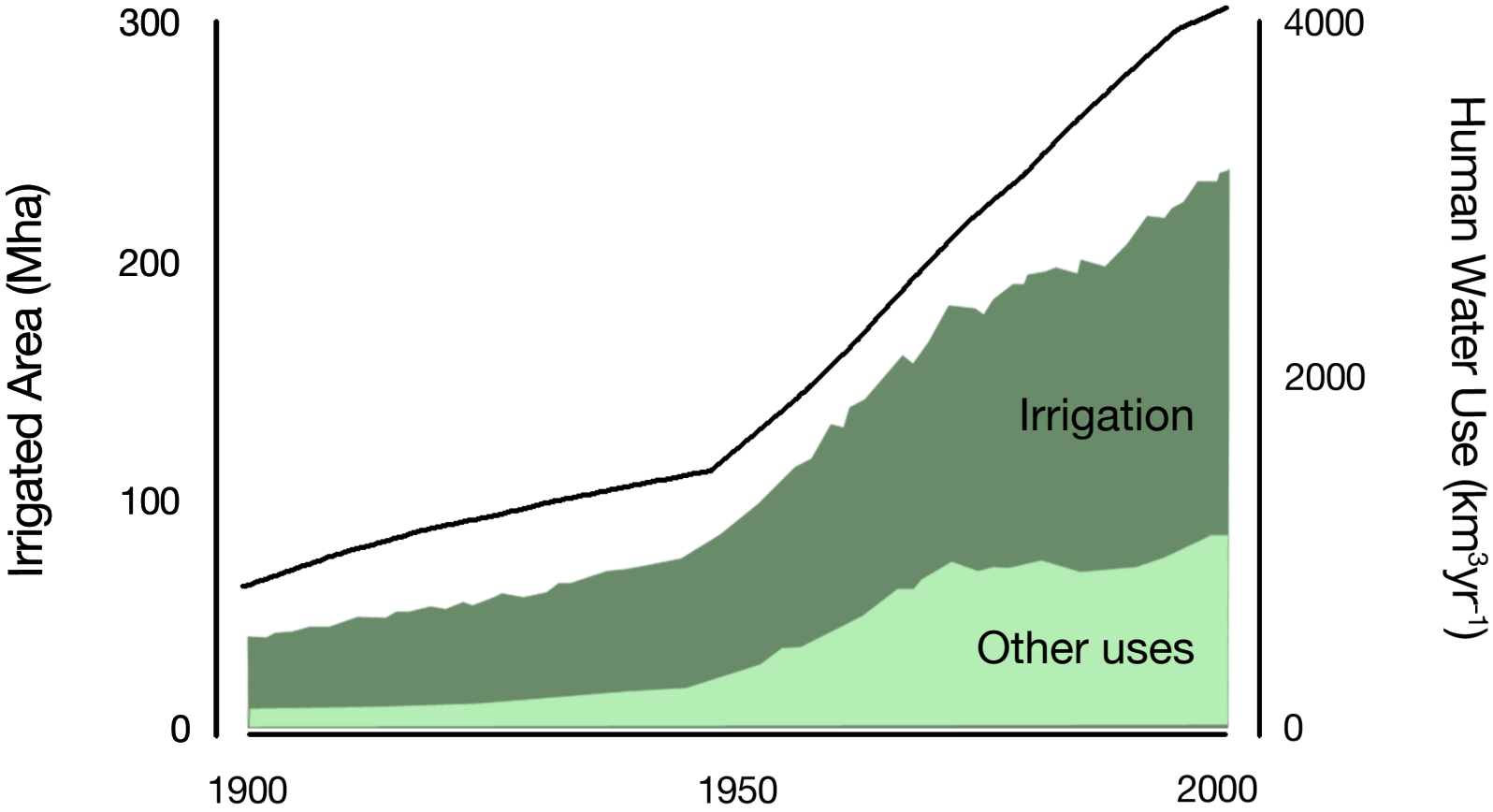
March 28, 2018

P I K
Potsdam Institute for Climate Impact Research
Humboldt-Universität zu Berlin

Human ingenuity as the ultimate resource

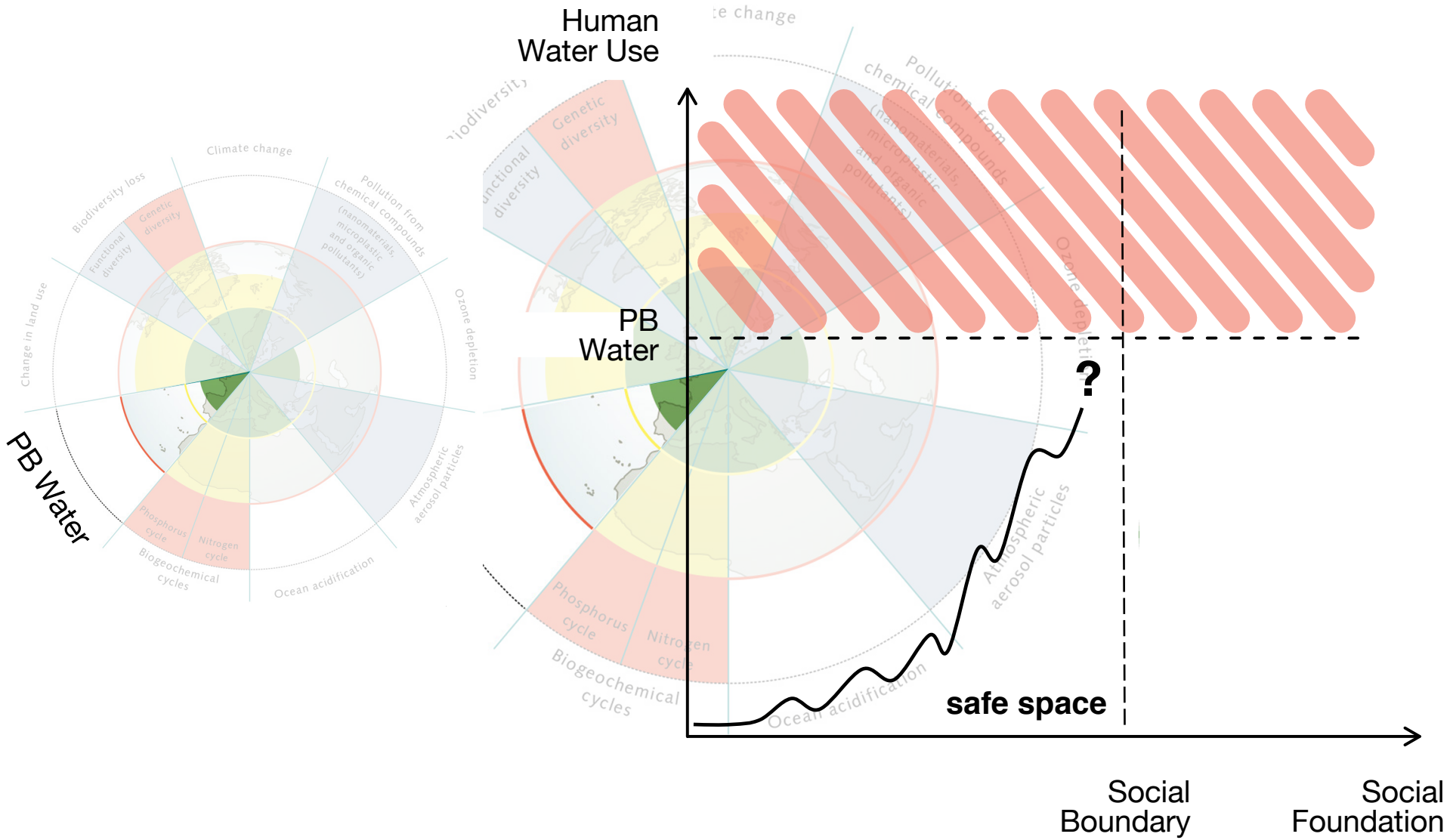


Growing societies in face of environmental limits



Adapted from: Siebert et al. (2015), Müller Schmied et al. (2016)

Concept of the *safe operating space for humanity*



Twin challenge: people and planet

Source: Stockholm Resilience Center

2.1
End hunger and achieve food security

6.4
Sustainable withdrawals

2.3
Double agricultural productivity

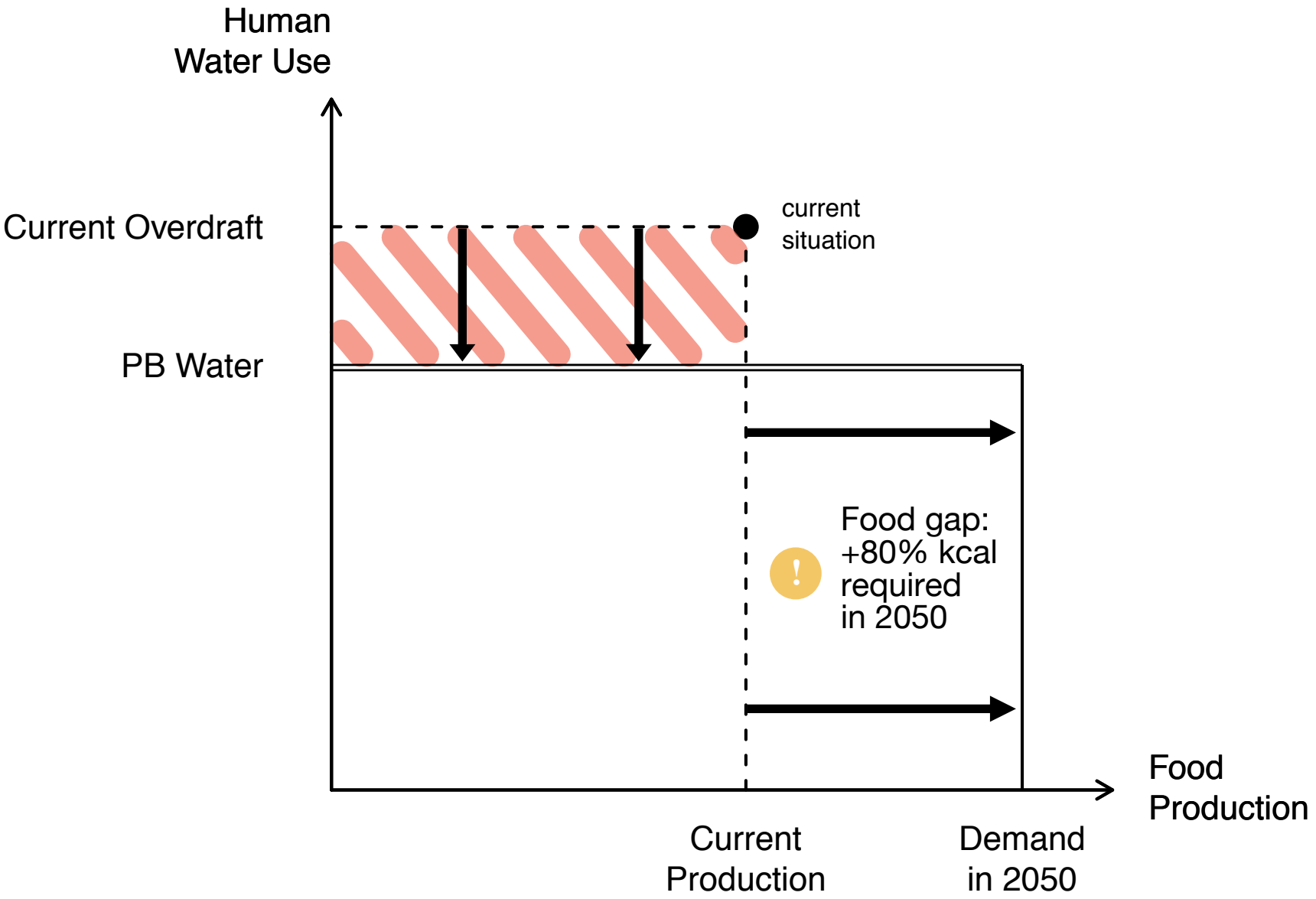
6.6
Protect and restore water ecosystems

2.4
Sustainable and resilient food pro-duction

=

?

Water and food as key factors



Research Questions

What does it take to respect PB water?

Status of PB water?

Constraints on food production?

1

1.1

1.2

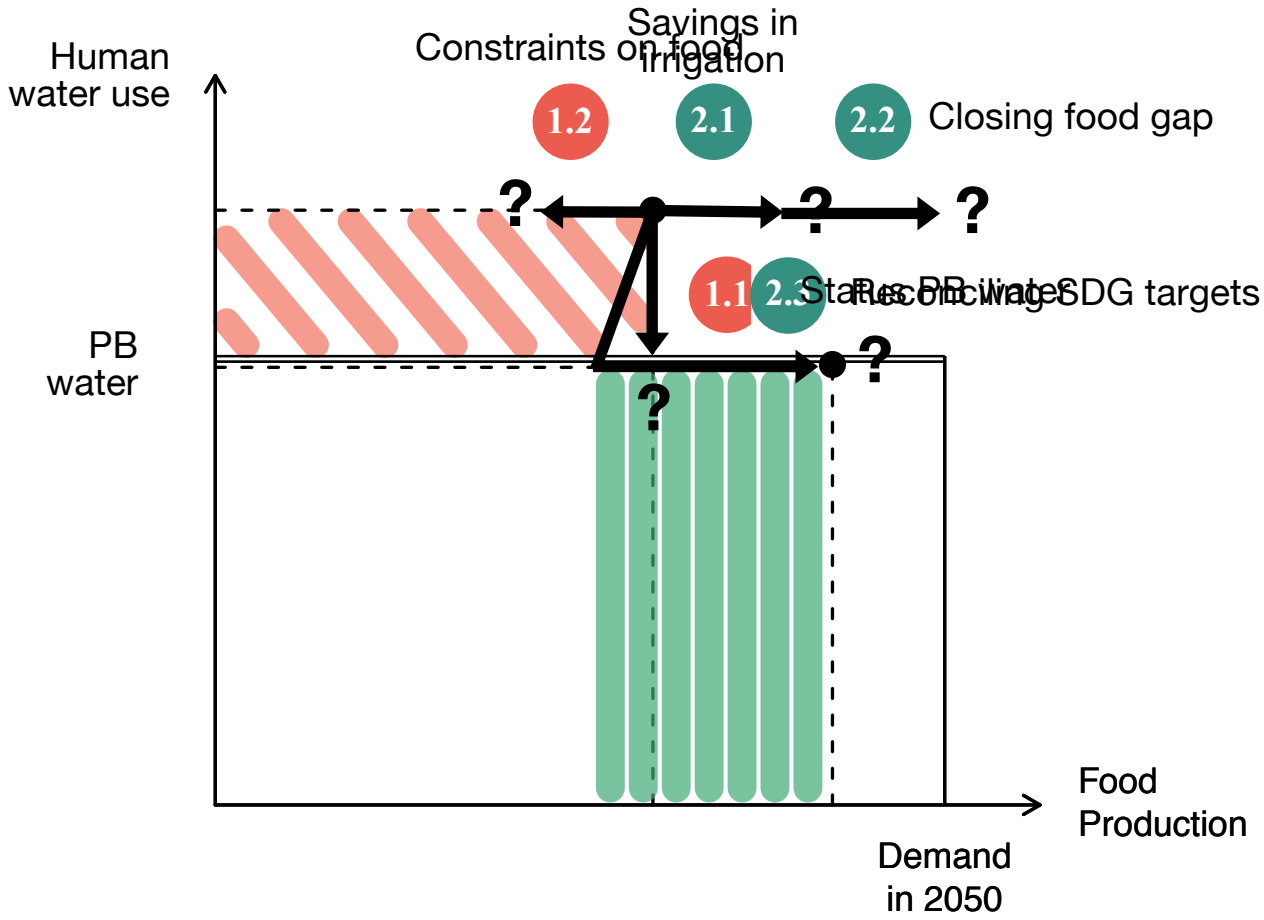
2

Food production potentials within PB water?

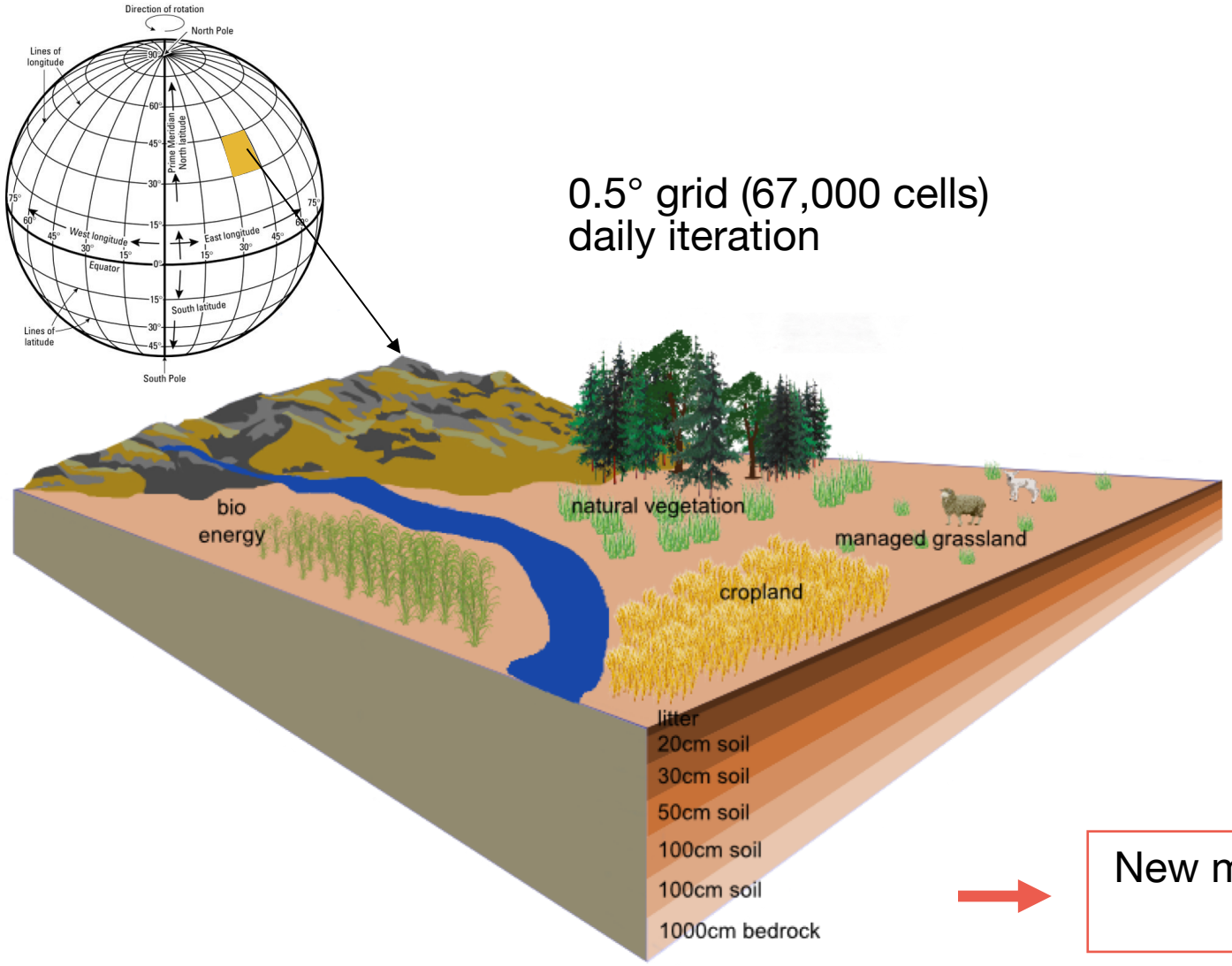
2.1 Saving potentials in irrigation?

2.2 Closing the food gap with integrated water management?

2.3 Reconciling SDG water and food targets?



Agro-hydrological modeling framework LPJmL



0.5° grid (67,000 cells)
daily iteration

Dynamic process representation

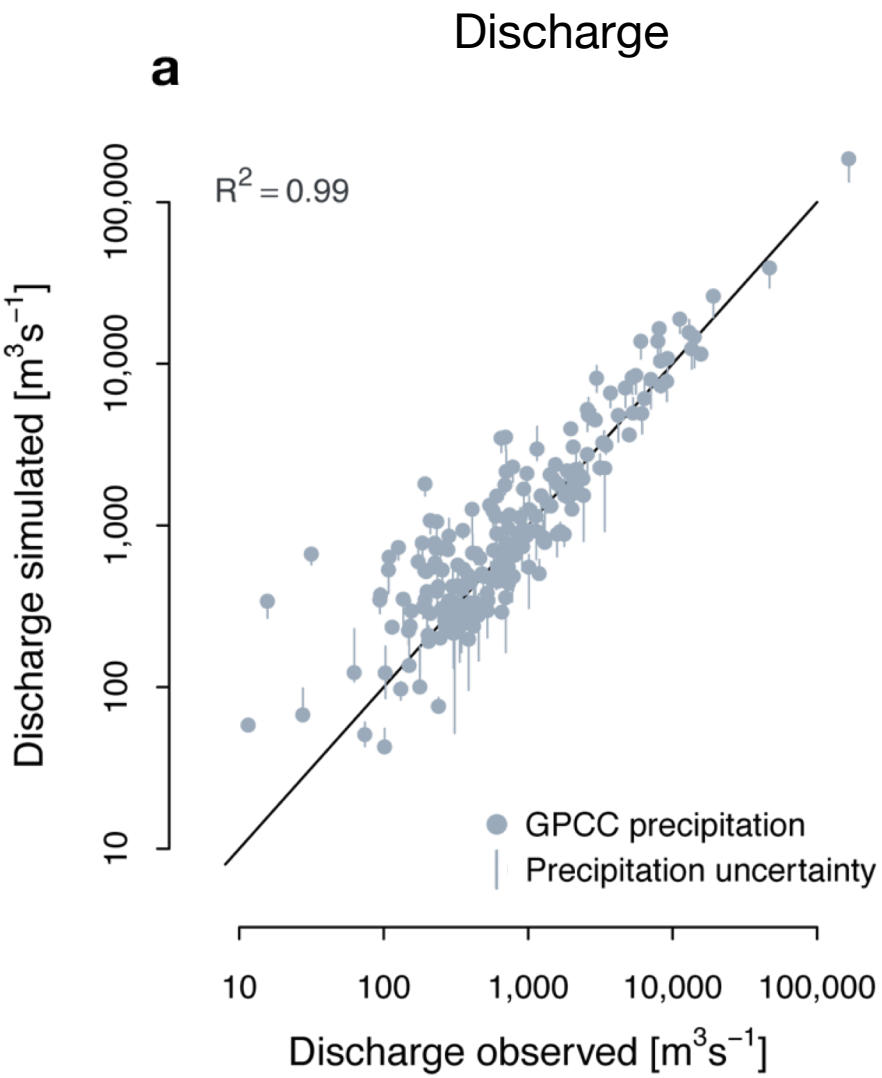
Agricultural model

Hydrological model

New mechanistic irrigation module

New mechanistic representation of environmental flows

LPJmL's capacity to simulate key variables



Jägermeyr et al. (2017), *Nature Comm.*

1 What does it take to respect PB water?

1.1 Status of PB water?

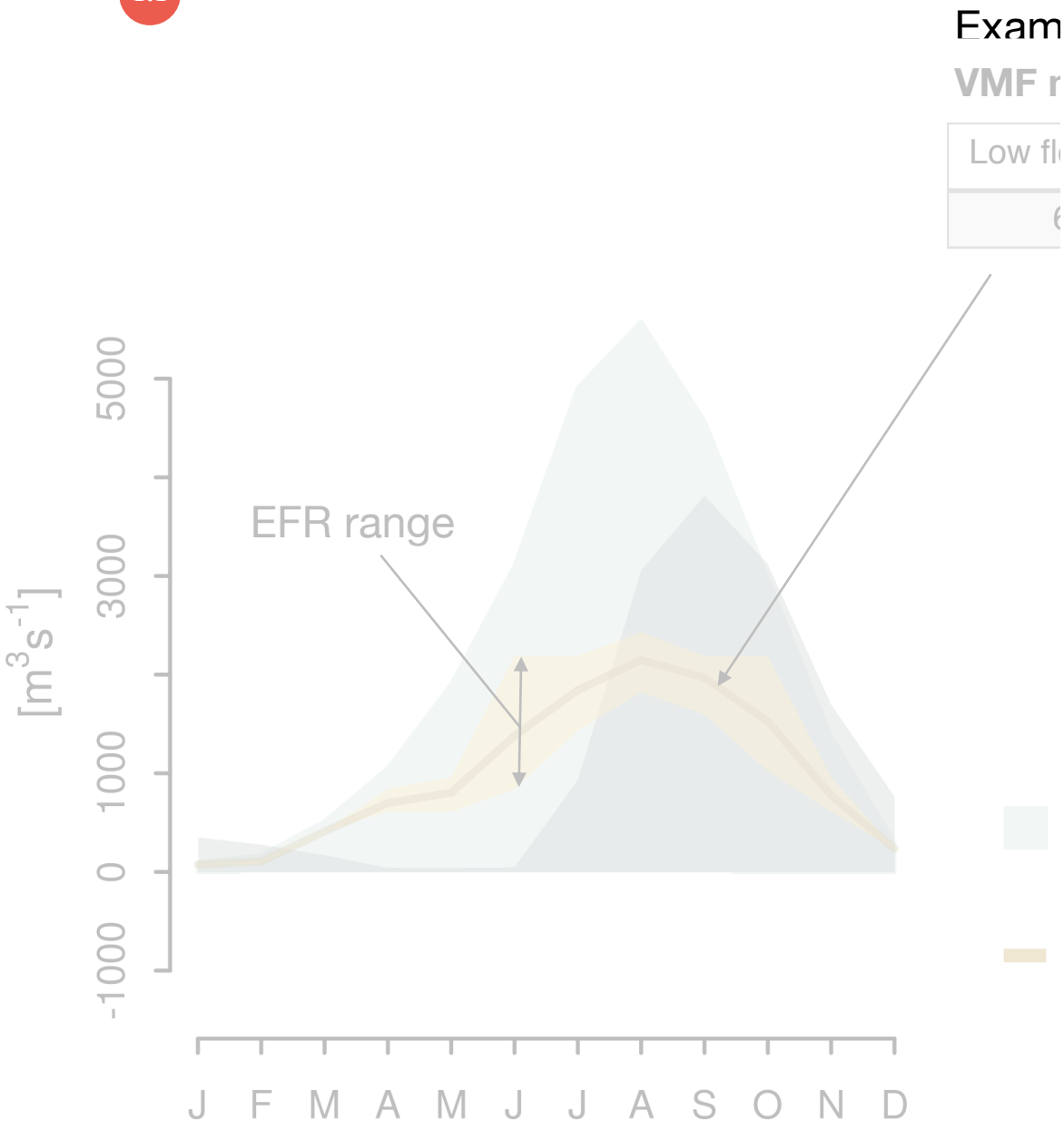
Conceptual revision of global PB water

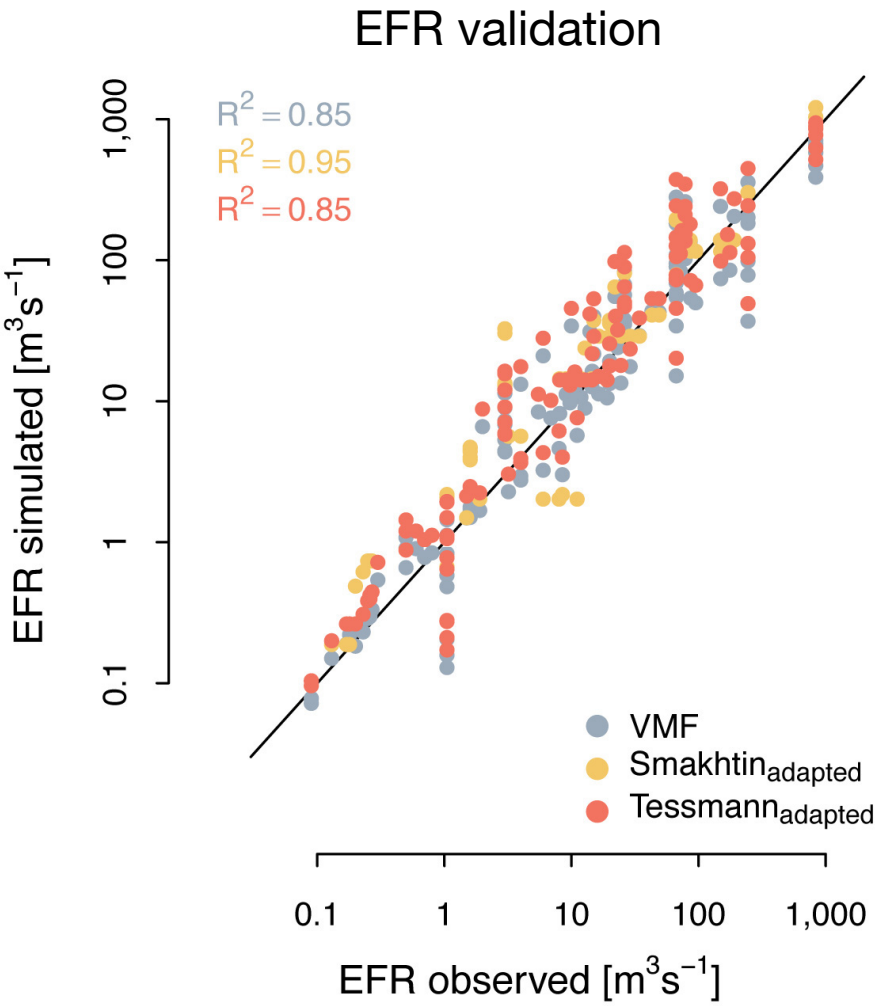
!

Water overdraft does not balance globally.

→ I refer to the **regional** water boundary hereinafter (PB water) via **environmental flow requirements**.

Regional PB water = Environmental Flow Requirements (EFRs)

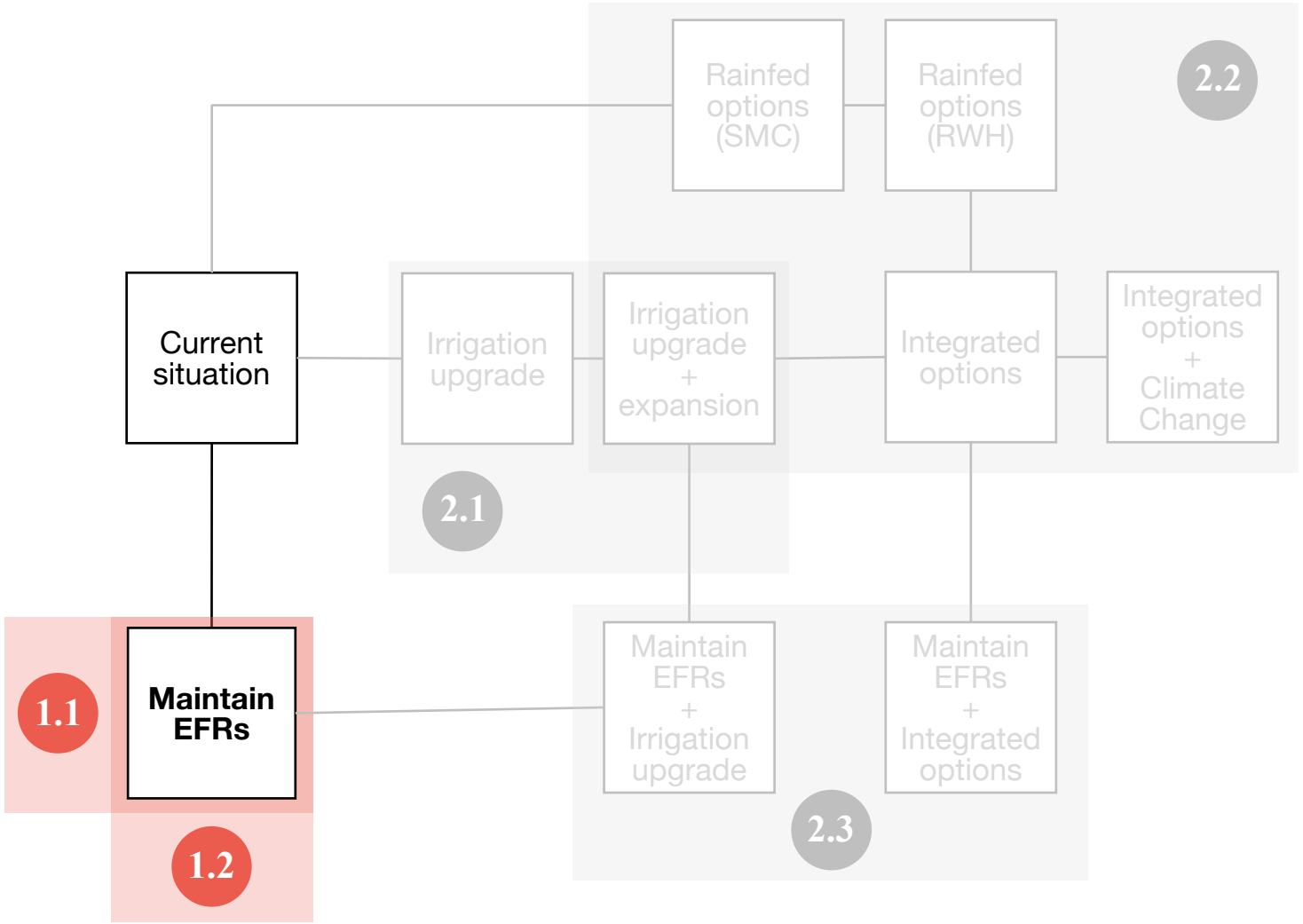




1 Respect PB water

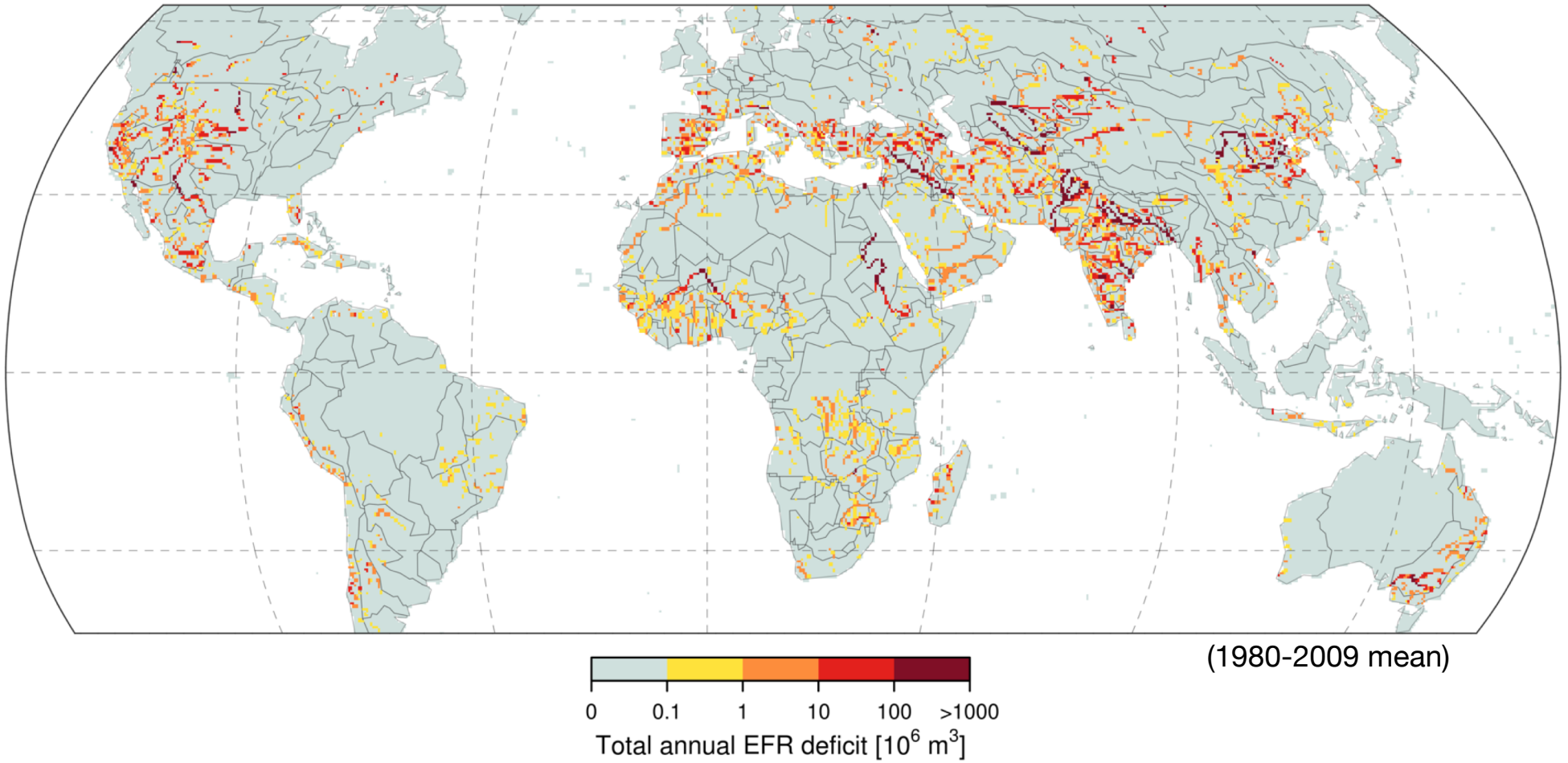
1.1

Simulation protocol: maintain EFRs



Simulation period: 1980-2009

Current global EFR violations



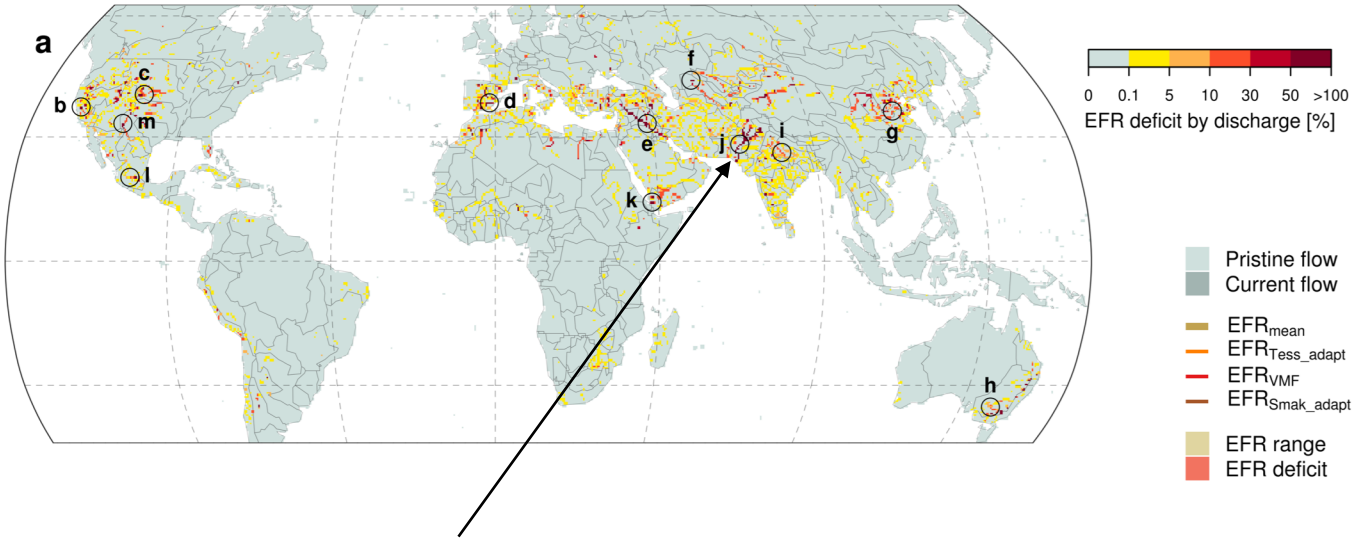
- Human water use:
  2400 km^3 irrigation
  1070 km^3 other uses

- 40% of today's irrigation water use at the expense of EFRs

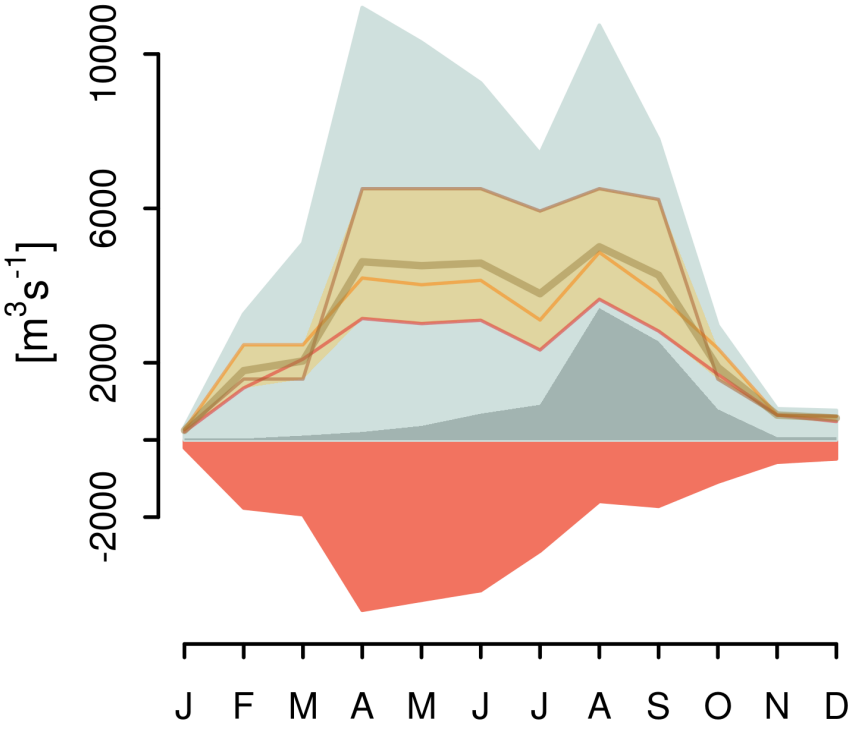
Jägermeyr et al. (2017), *Nature Comm.*

1 Respect PB water

1.1



Pakistan, Indus River



Jägermeyr et al. (2017), *Nature Comm.*

1 **What does it take to respect PB water?**

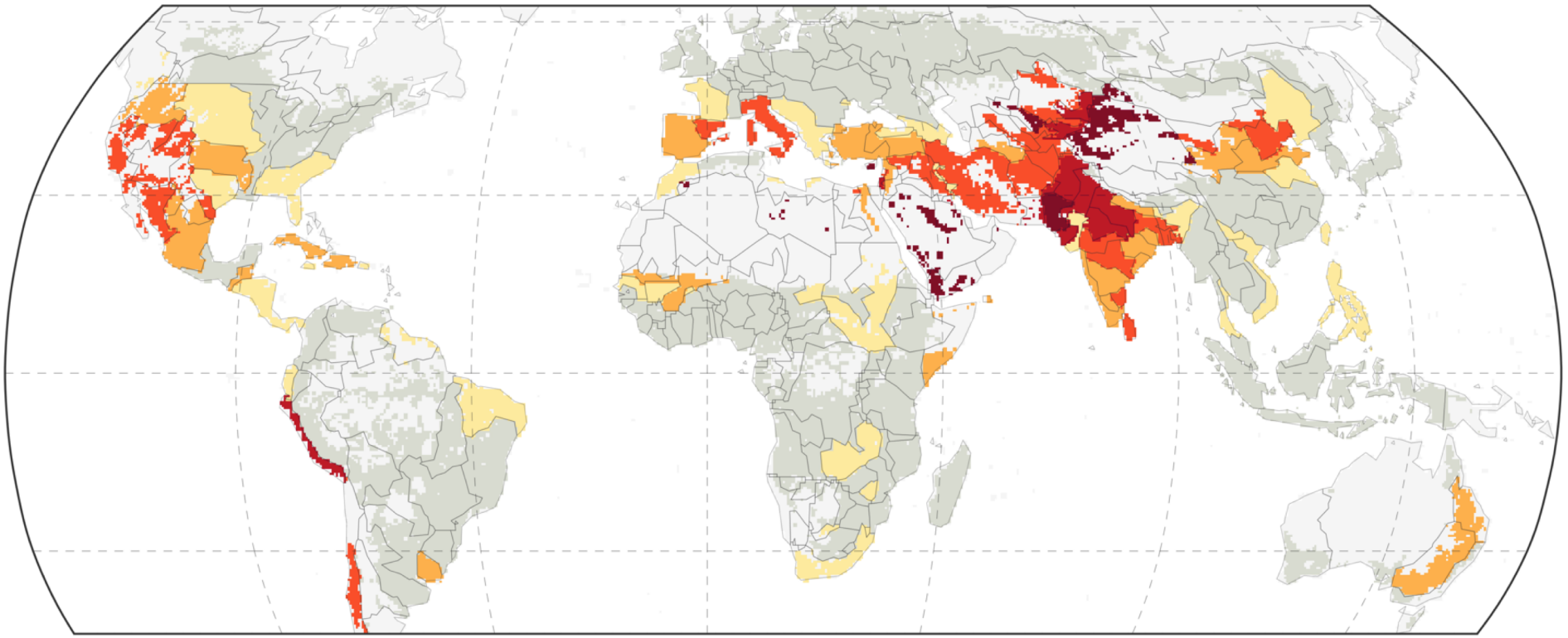
1.1 Status of PB water?

1.2 Constraints on food production?

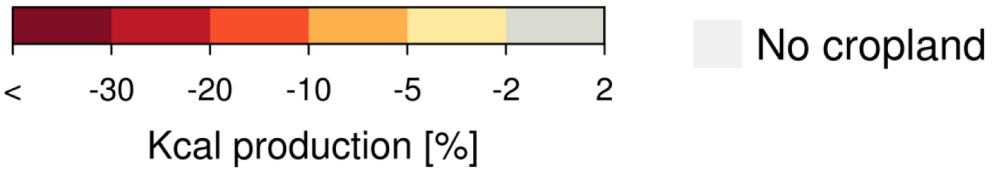
EFR constraints on food production

! Half of irrigated cropland faces ≥10% kcal loss

! >20% of total production depends on EFRs in hot-spot regions



(1980-2009 mean)



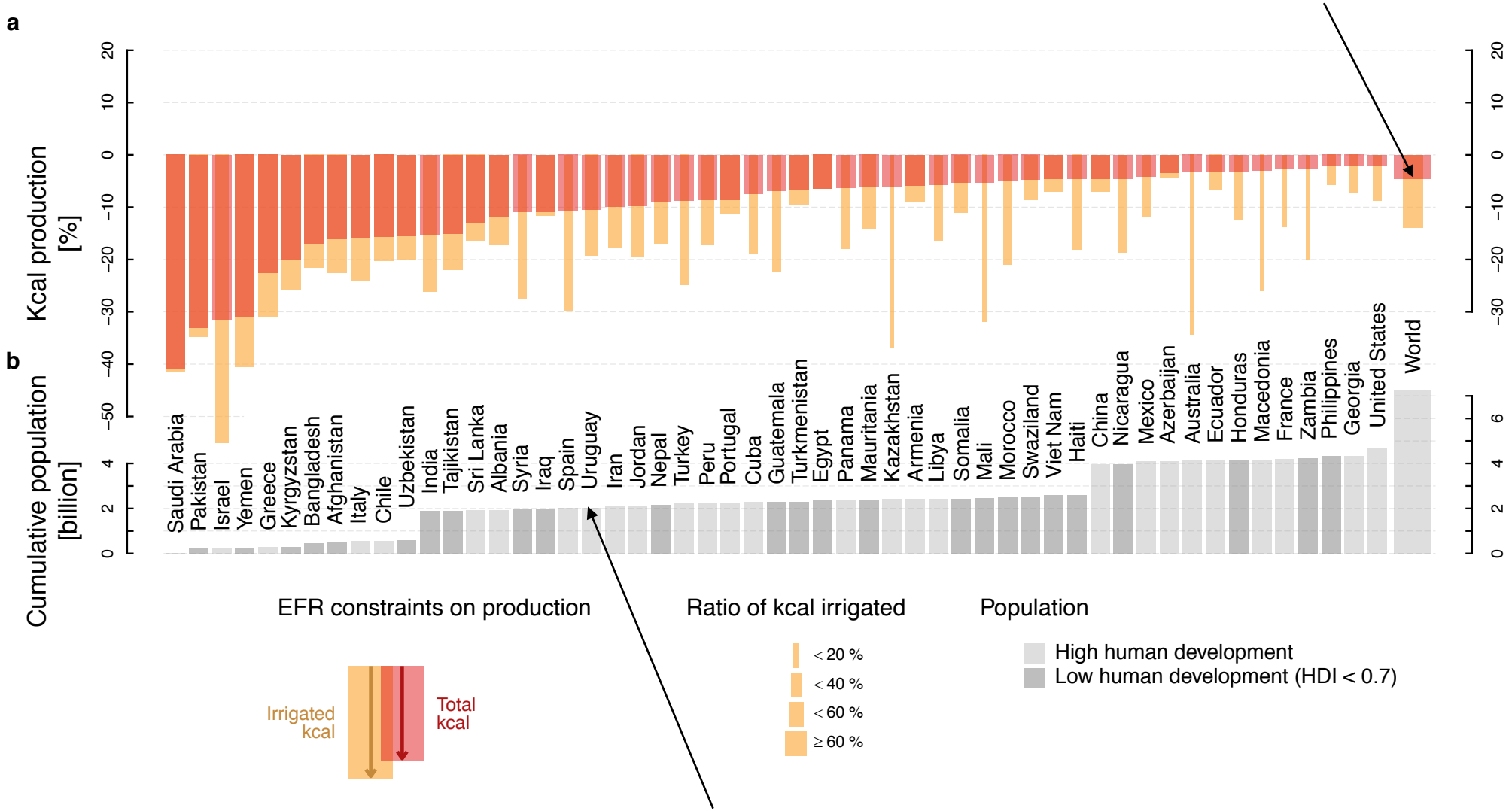
Jägermeyr et al. (2017), *Nature Comm.*

1 Respect PB water

1.2

EFR constraints on food production

5% production loss at global level

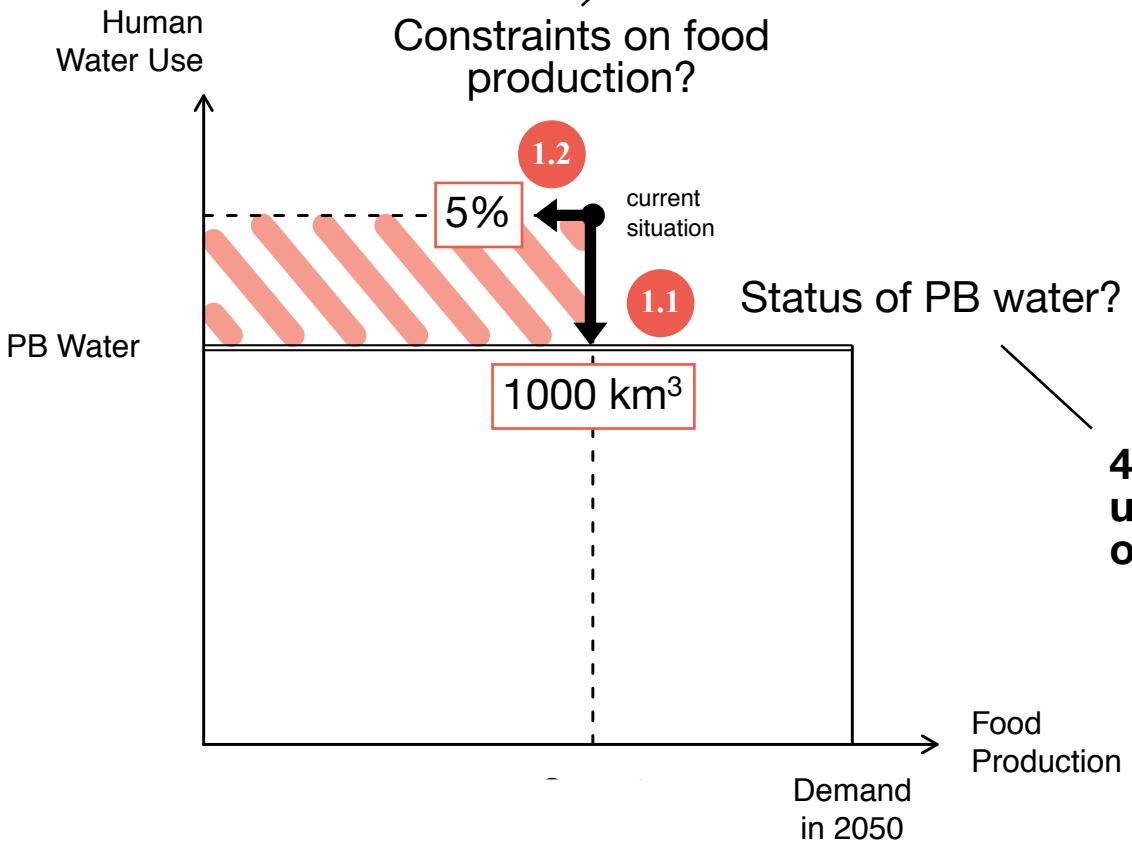


2 billion people live in countries facing >10% production loss

Jägermeyr et al. (2017), *Nature Comm.*

Summary: What does it take to respect PB water?

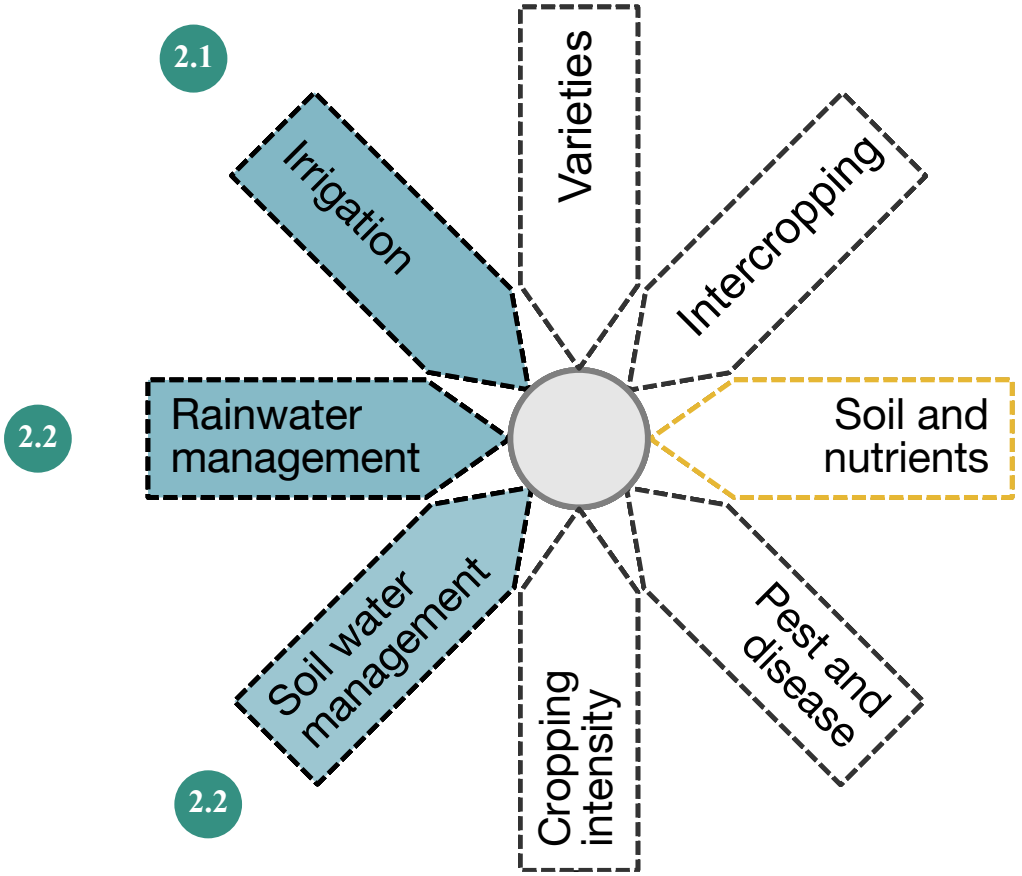
Maintaining EFRs would impinge on 30% of irrigation's contribution to food production.



40% (1000 km^3) of irrigation water use is unsustainable – at the cost of ecosystems

2 Food production potentials within PB water?

Options for sustainable intensification



2 Food production potentials within PB water?

2.1 Saving potentials in irrigation?

Global mechanistic representation of irrigation systems

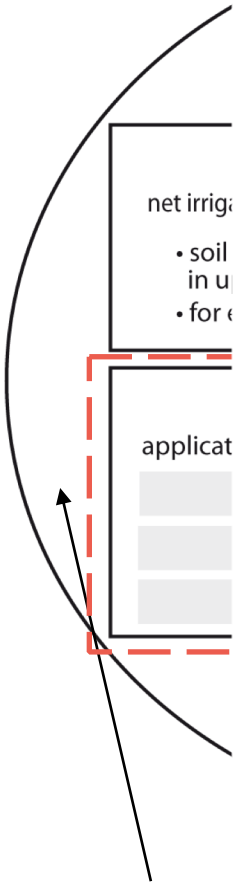
Surface irrigation

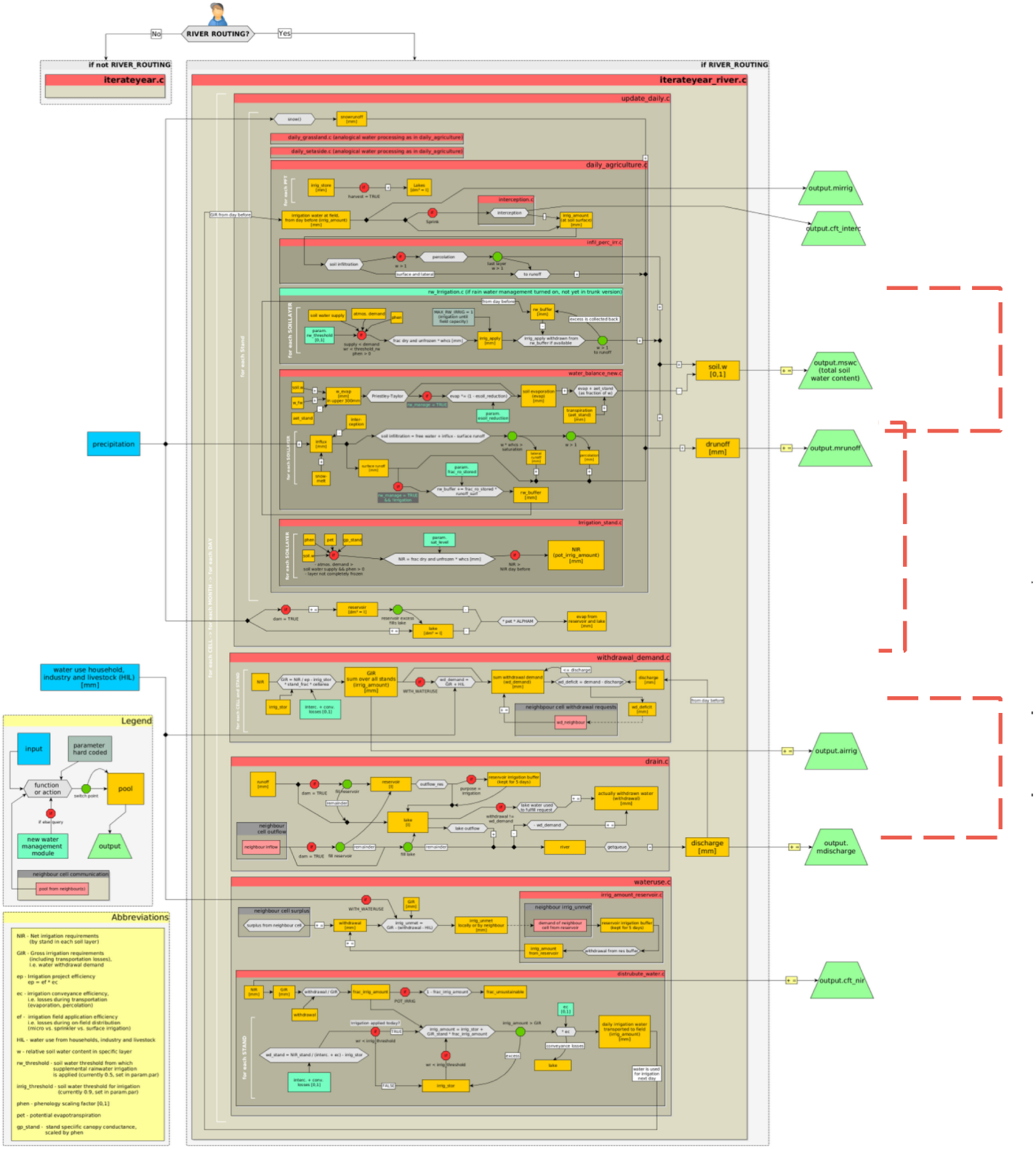
Sprinkler irrigation

Drip irrigation

2 Food productic potentials

2.1

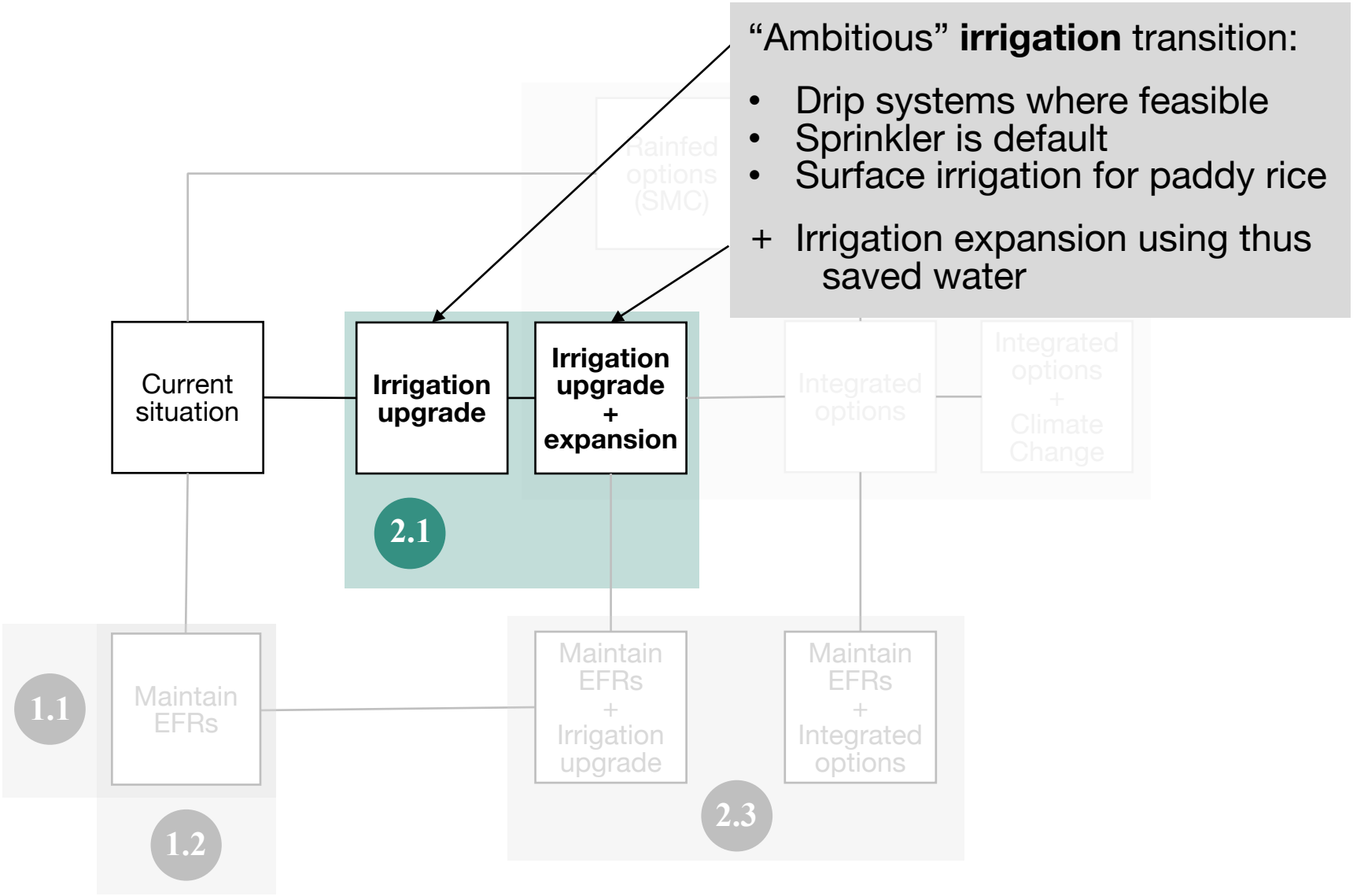




! No explic nonrenew

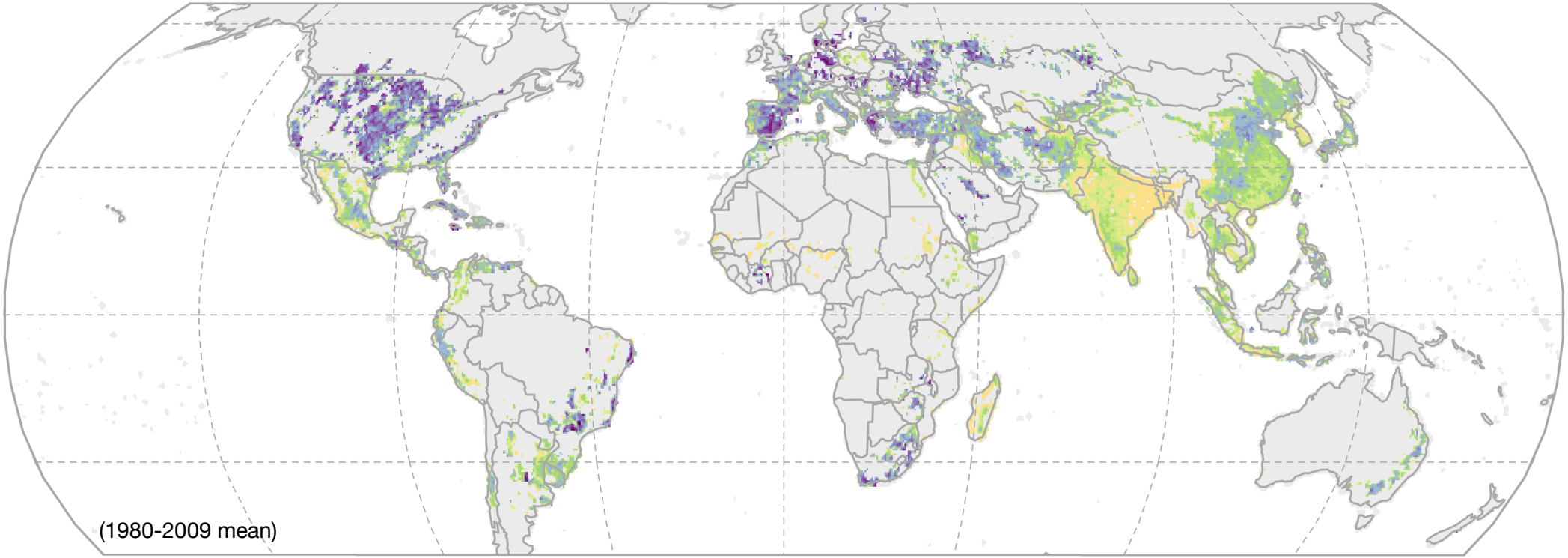
Jägermeyr et al. 2015

Simulation protocol: irrigation upgrade



Simulation period: 1980-2009

Global gridded map of irrigation efficiencies



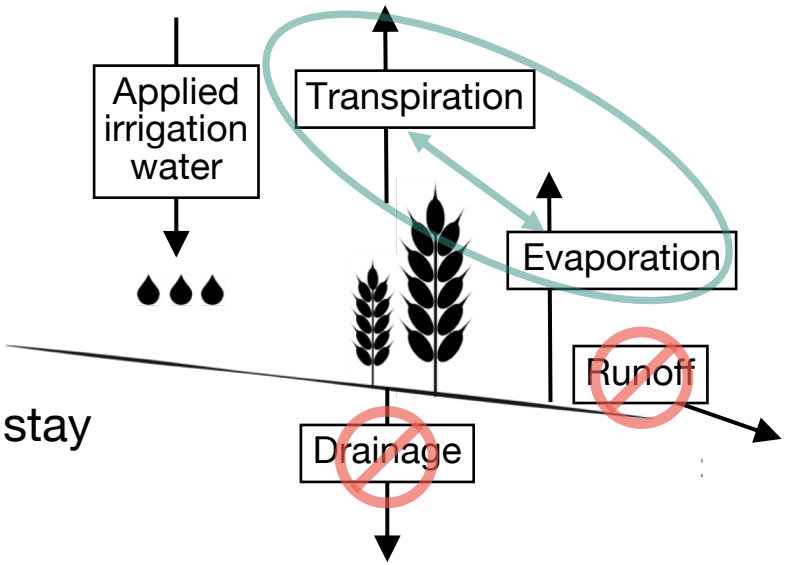
	Surface	Sprinkler	Drip
Rohwer et al. 2007	27	45	71
Sauer et al. 2010	24	51	70
This study	29	51	70

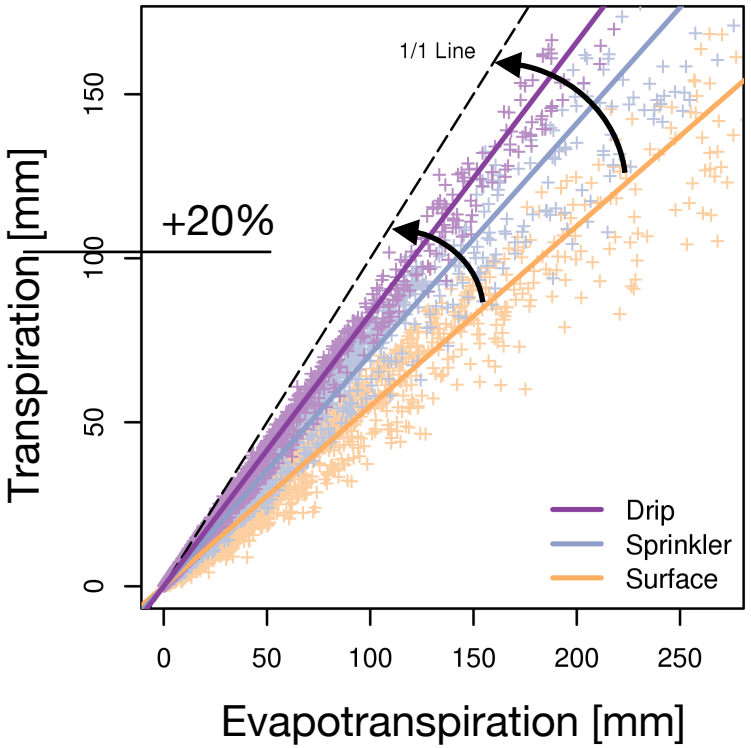
! Global average irrigation efficiency at 33%

! 50% of consumptive water use is currently lost (600 km^3)

Jägermeyr et al. 2015, *HESS*

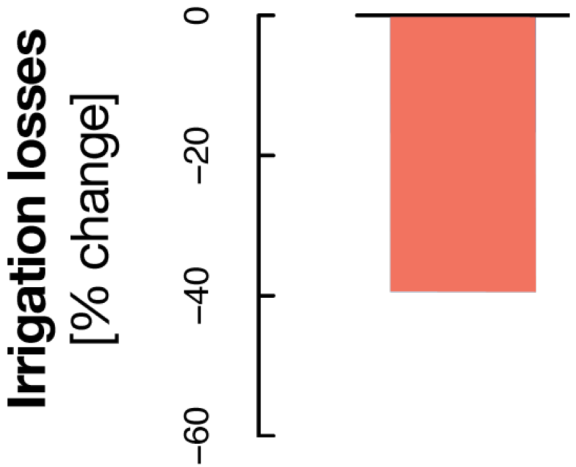
Potential of irrigation water savings





- Return-flows stay untouched

- 40% of irrigation losses are savable



"Ambitious" irrigation transition:
- Drip systems where feasible
- Sprinkler is default
- Surface irrigation for paddy rice

Jägermeyr et al. 2016, *ERL*

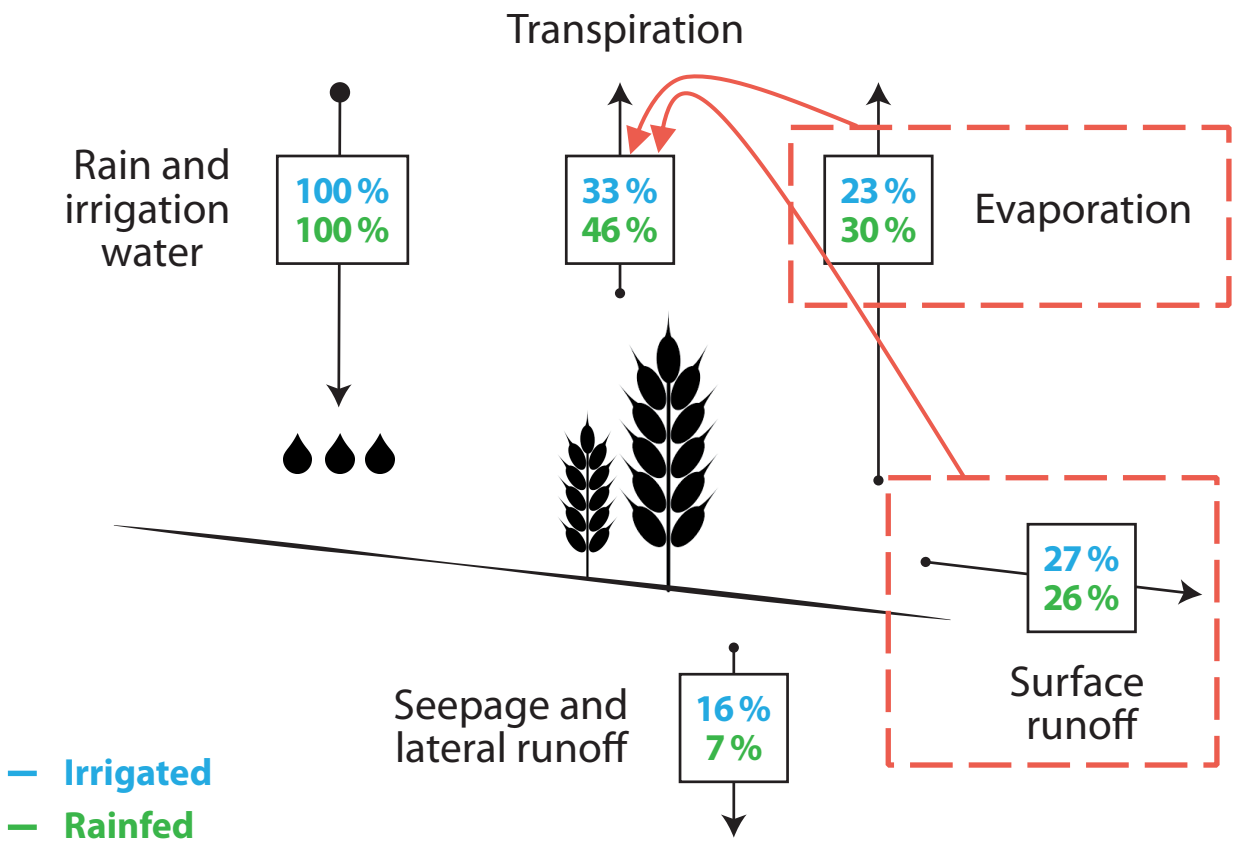
2 Food production potentials within PB water?

2.1 Saving potentials in irrigation?

2.2 Closing the food gap with integrated water management?

Hydro-climatic opportunities

Only 40% of water used productively



Jägermeyr et al. 2016, *ERL*

Rain-fed management options

1. **Soil moisture conservation (SMC)**
2. **Water harvesting (WH)**

Nature, 2015 (519)

COMMENT

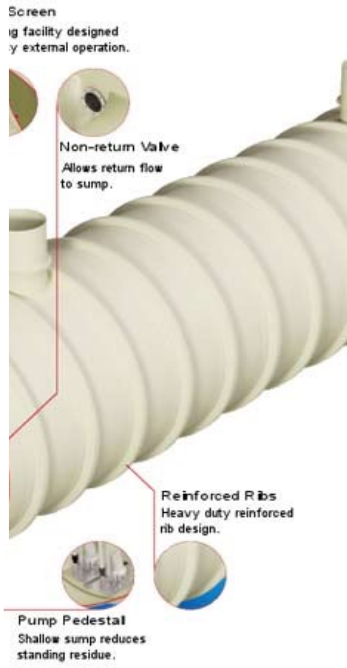
RECRUITMENT Tips for hiring leaders emphasize emotional intelligence **p.286**

PLANTS A symbiotic story of seeds and civilization **p.288**

THEATRE The toll and the triumph of a life with OCD takes centre stage **p.289**

OBITUARY Charles H. Townes, laser co-inventor, remembered **p.292**

Terraced fields in the Simien Mountains, Ethiopia, help to conserve soil moisture.



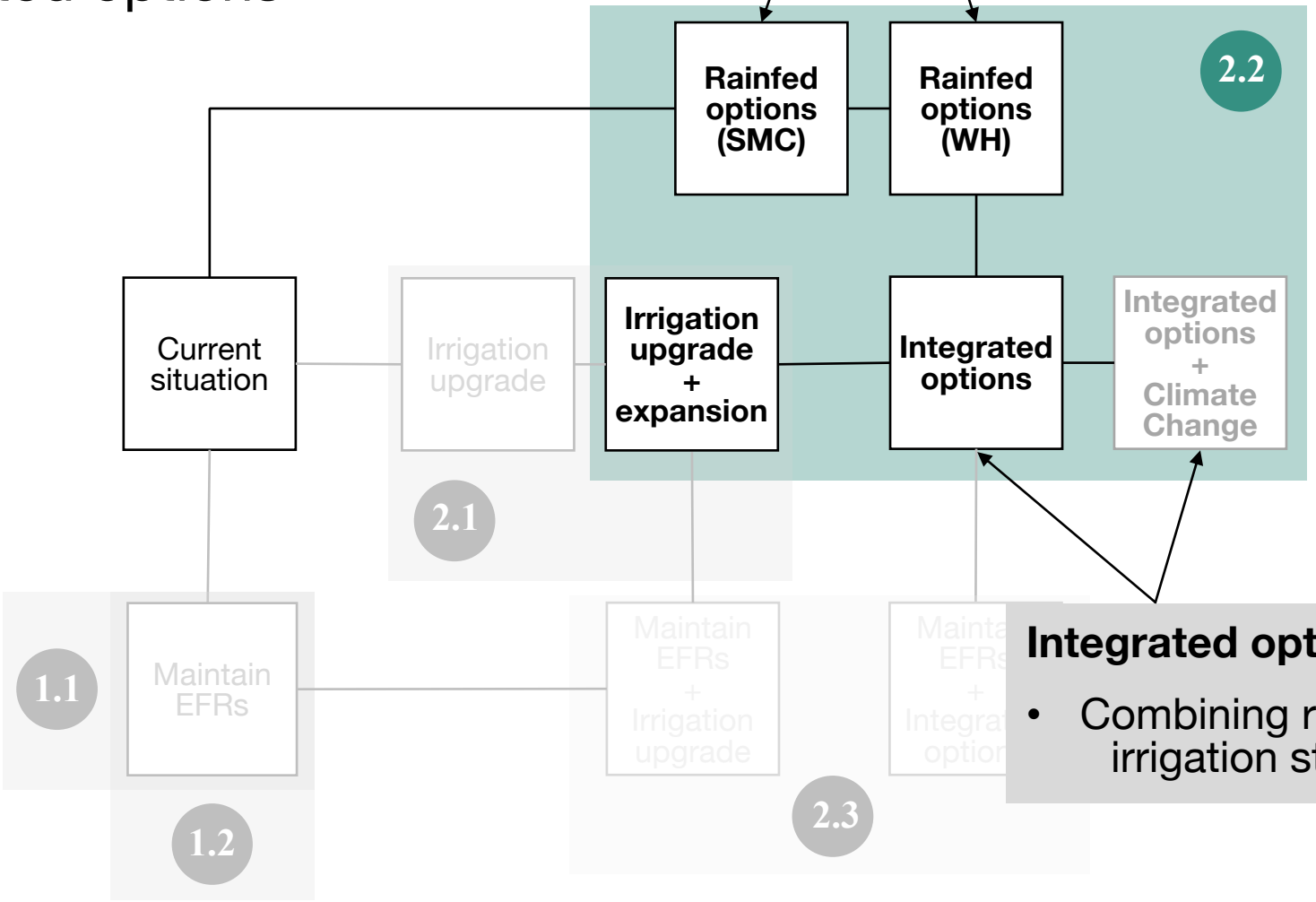
Increase water harvesting in Africa

Meeting global food needs requires strategies for storing rainwater and retaining soil moisture to bridge dry spells, urge **Johan Rockström** and **Malin Falkenmark**.

Simulation protocol: integrated options

"Ambitious" **rainwater** management:

- 50% alleviation of bare soil evaporation
- Collecting 50% surface runoff for supplemental irrigation

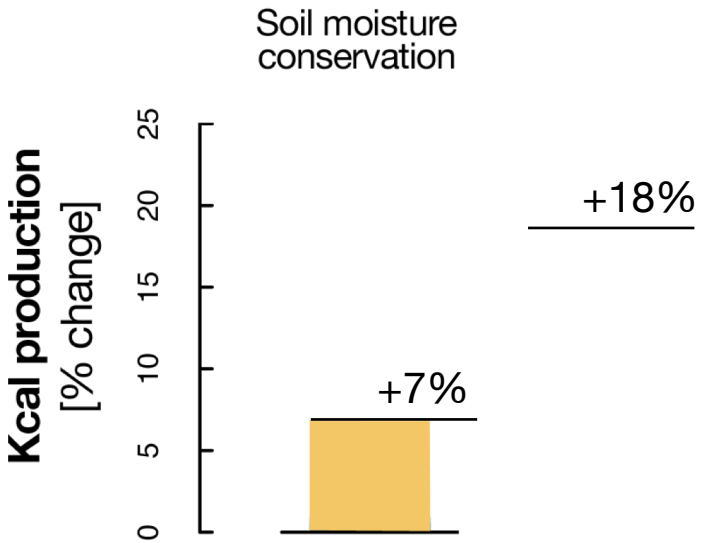


Integrated options:

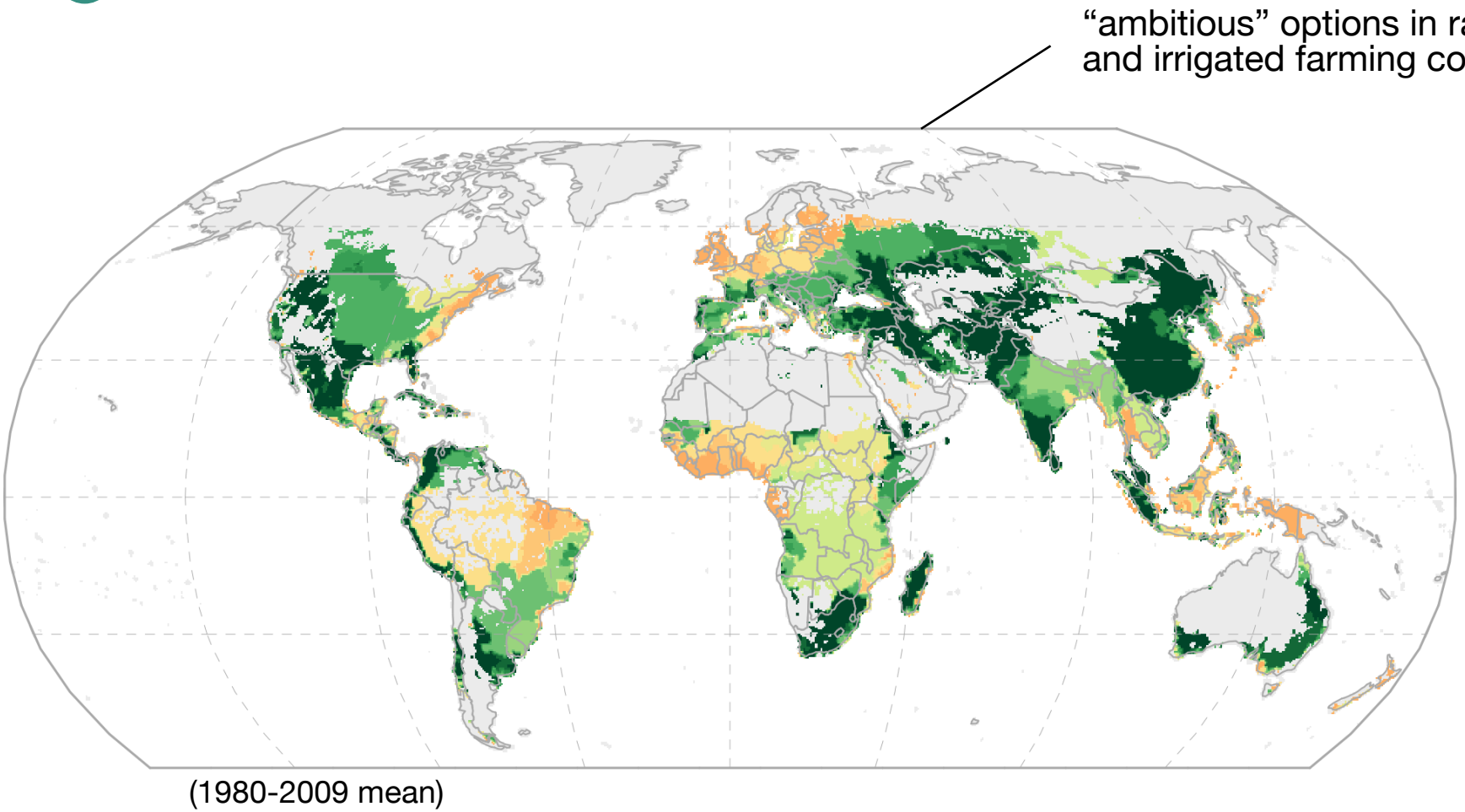
- Combining rainfed and irrigation strategies

Simulation period: 1980-2009

Food production opportunities in rainfed farming



Integrated options

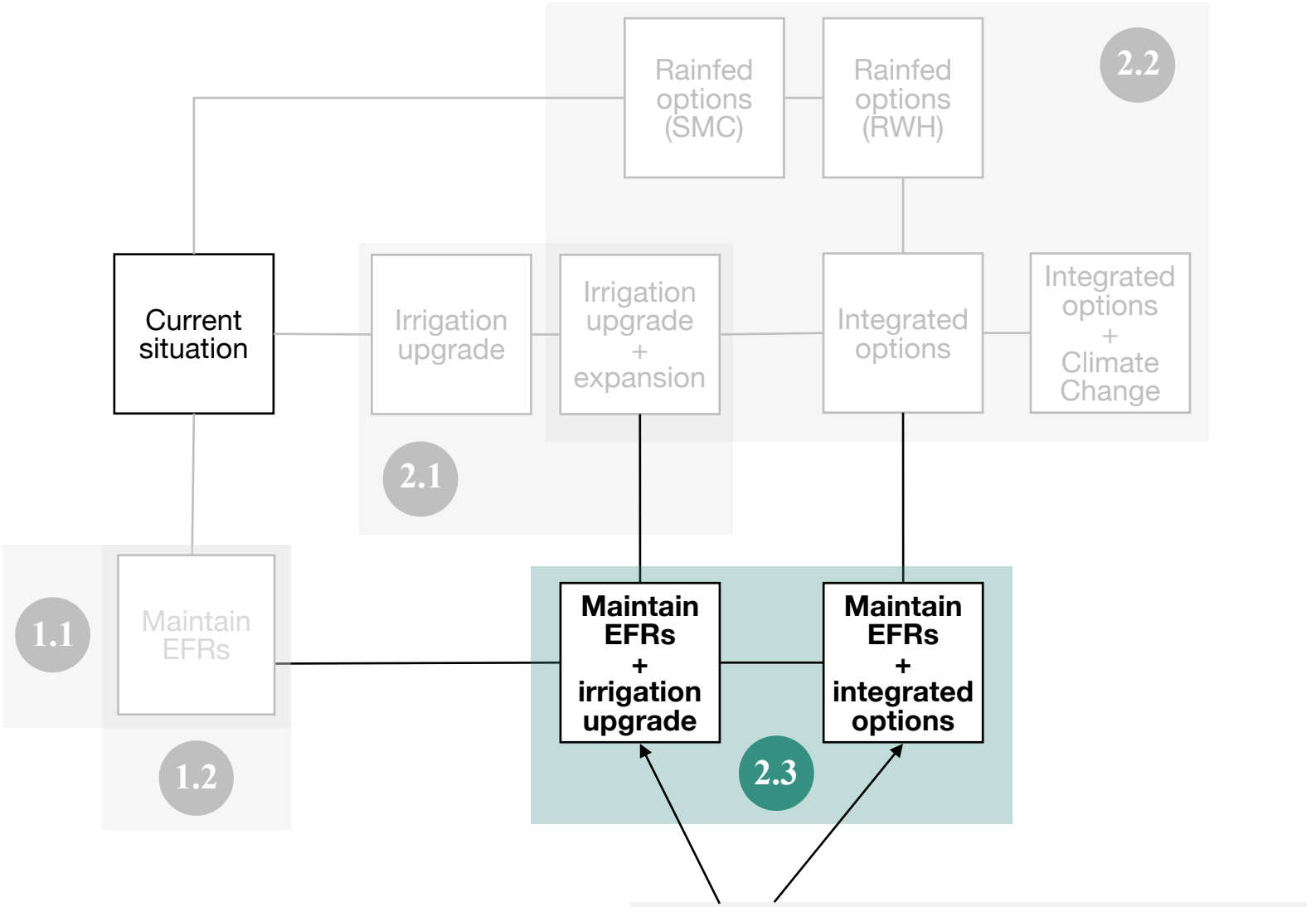


- Global +40% kcal gain
- No land expansion
- Reduced water use

2 Food production potentials within PB water?

- 2.1 Saving potentials in irrigation?
- 2.2 Food gap under integrated water management?
- 2.3 Reconciling SDG water and food targets?

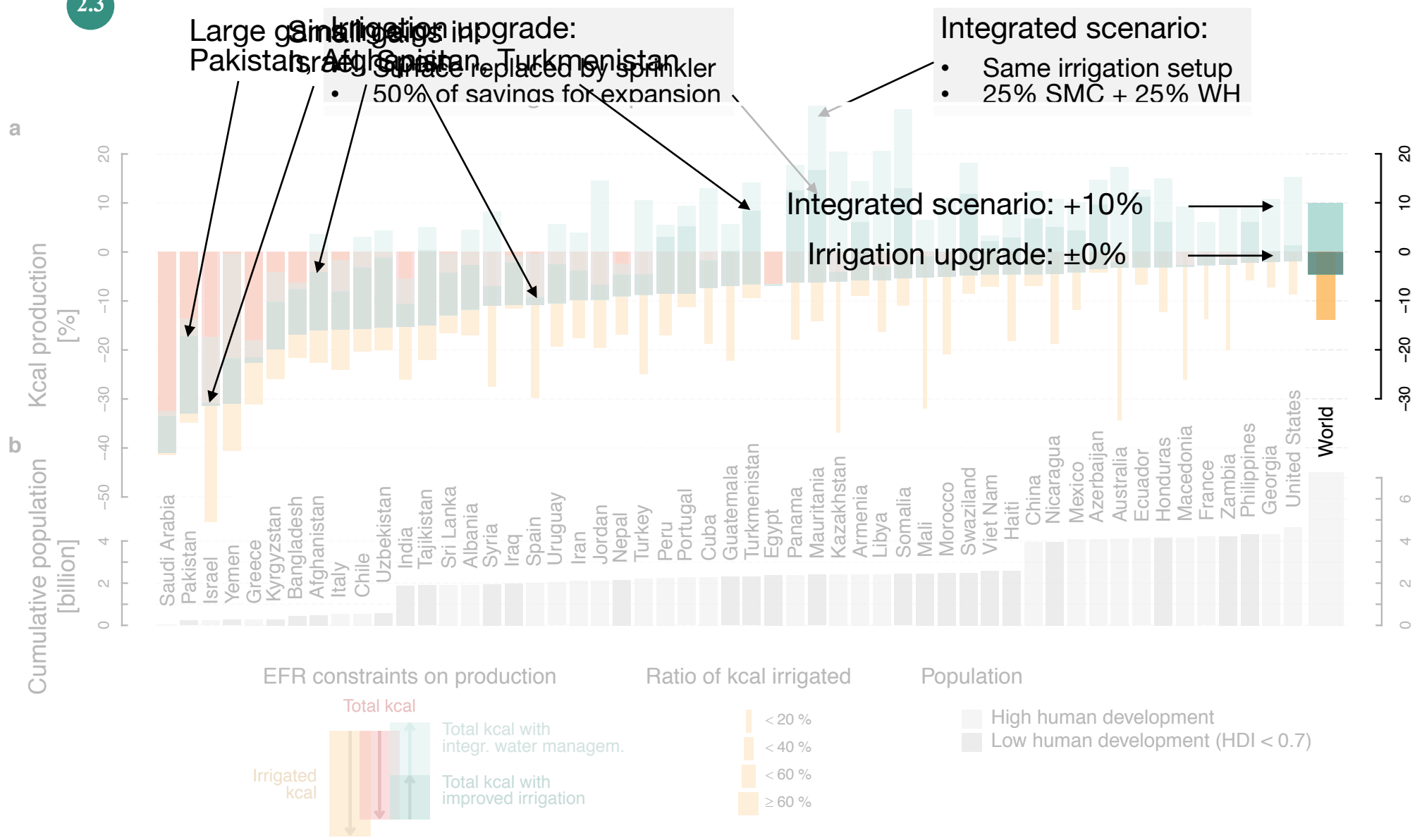
Simulation protocol: EFRs and water management



Simulation period: 1980-2009

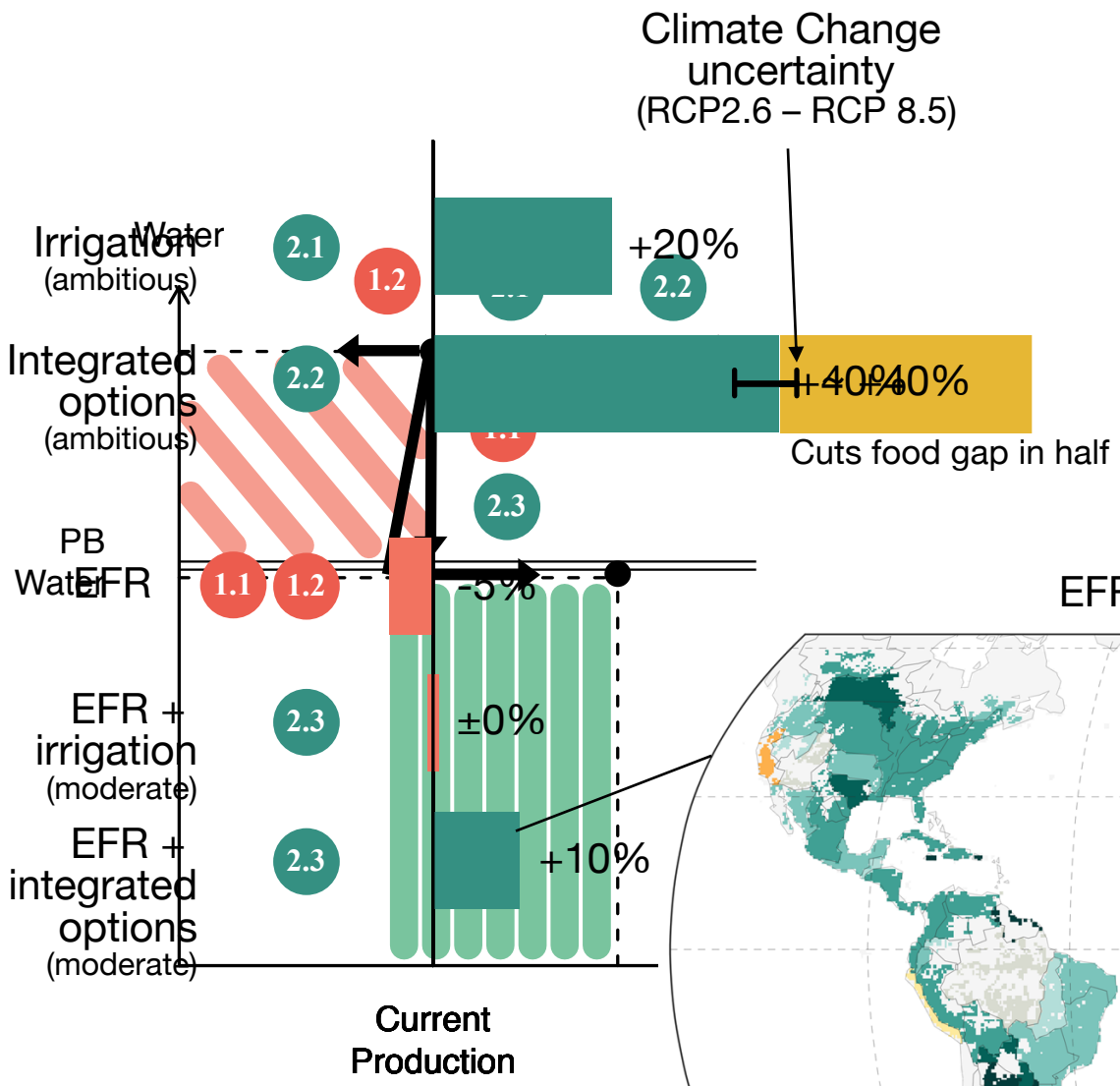
"moderate" intensity scenarios only

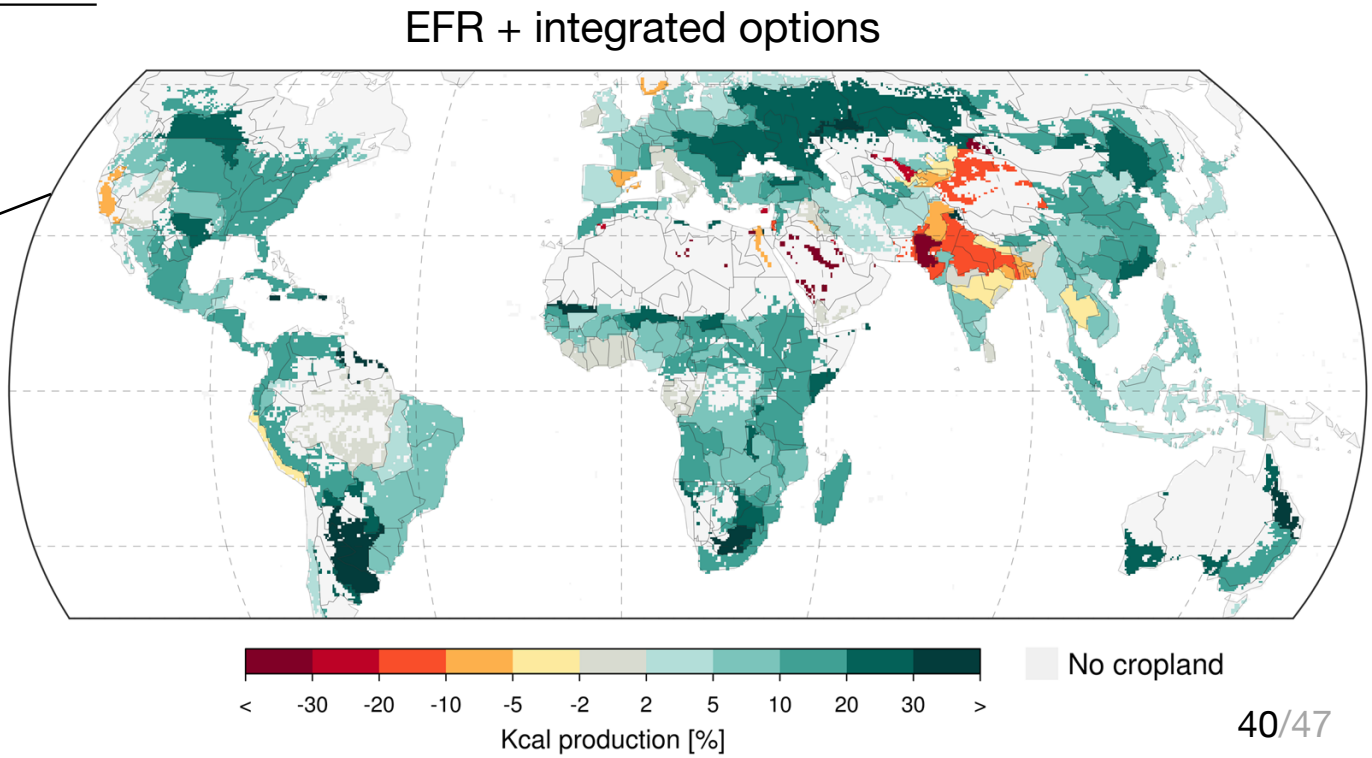
Reconciling EFRs and food production across countries



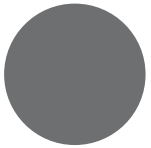
Jägermeyr et al. (2017), *Nature Comm.*

Summary: Food production potentials within PB water

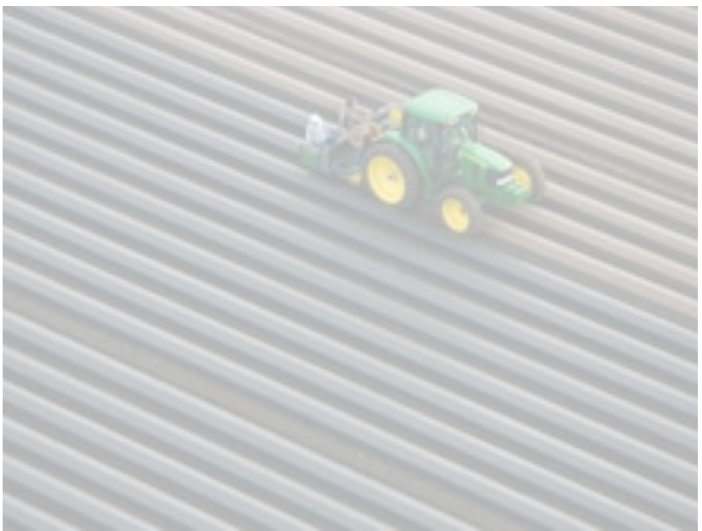


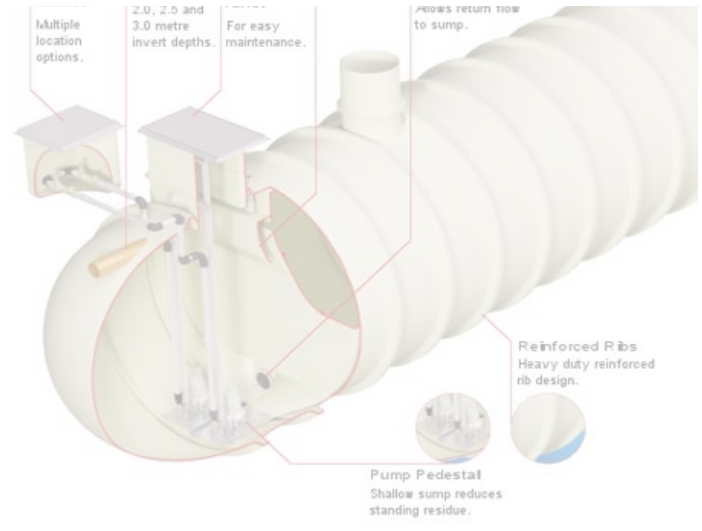


Jägermeyr et al. (2017), *Nature Comm.*

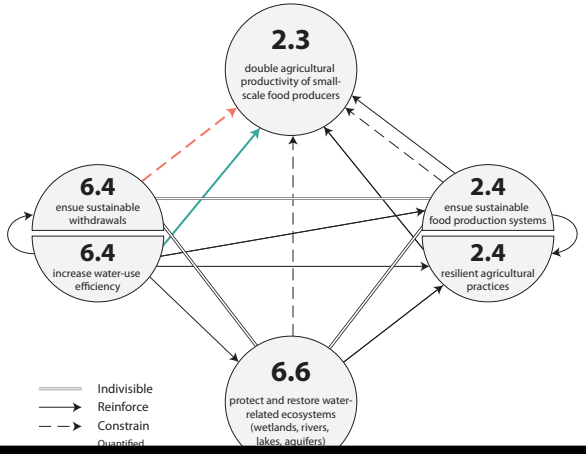


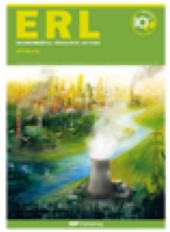
Synthesis




Multiple location options.
2.0, 2.5 and 3.0 metre invert depths.
For easy maintenance.
Allows return flow to sump.
Reinforced Ribs
Heavy duty reinforced rib design.
Pump Pedestal
Shallow sump reduces standing residue.

Synthesis





ERL

ENVIRONMENTAL RESEARCH LETTERS

This is to certify that the article

Integrated crop water management might sustainably halve the global food gap
by J Jägermeyr, D Gerten, S Schaphoff, J Heinke, W Lucht and J Rockström

has been selected by the editors of *Environmental Research Letters* for inclusion in the exclusive 'Highlights of 2016' collection. Papers are chosen on the basis of referee endorsement, originality, scientific impact and breadth of appeal.

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IDEAS INNOVATION

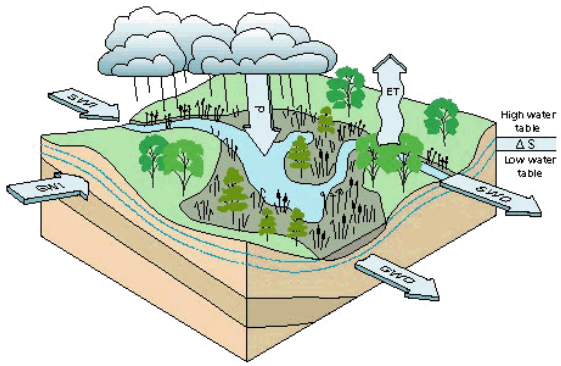
How to Cut the Global Food Gap In Half

The Aspen Institute @AspenInstitute | Feb. 16, 2016

IDEAS *The Aspen Institute is an educational and policy studies organization based in Washington, D.C.*

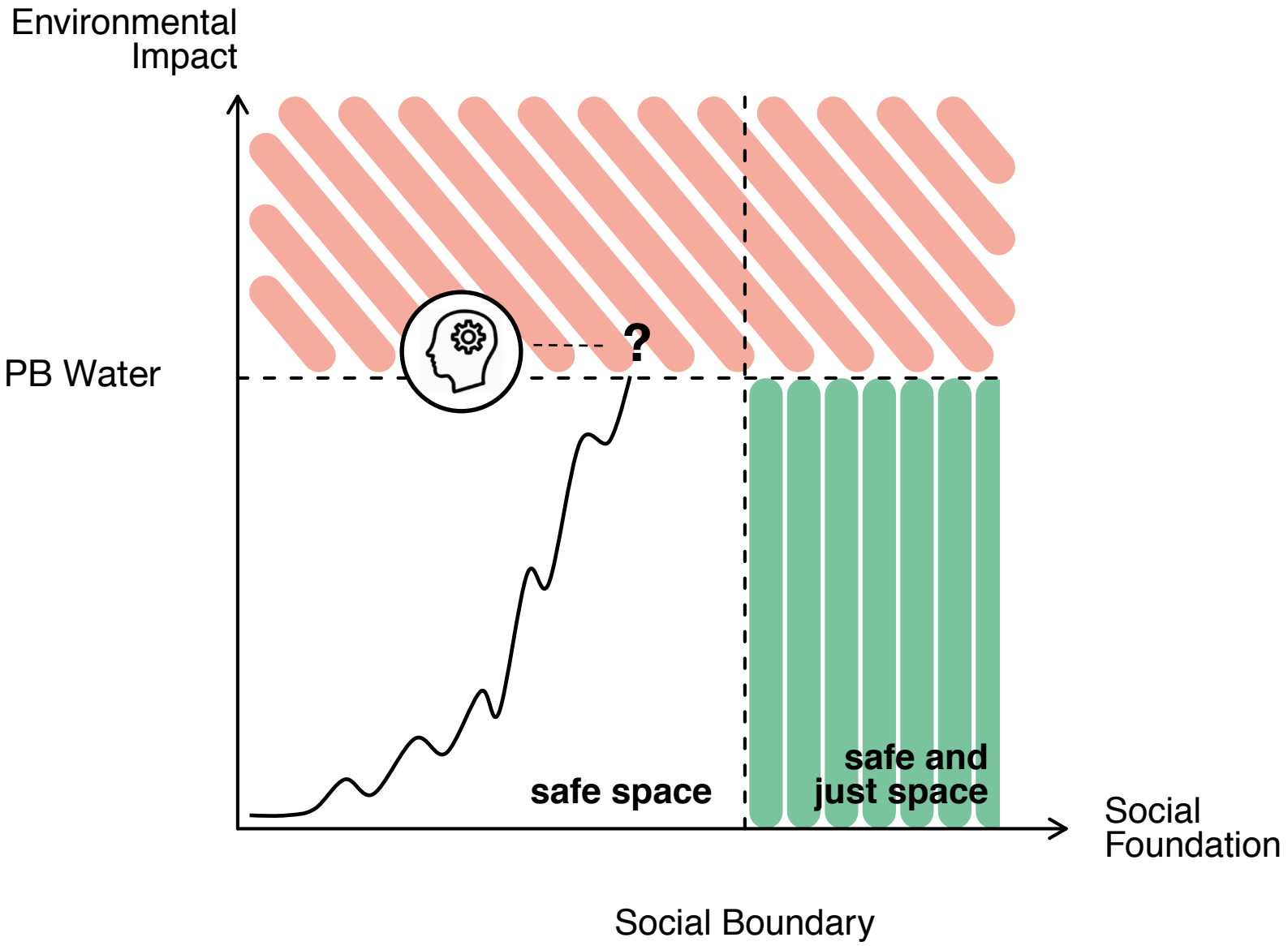
These are today's best ideas

1. Here's how we could cut the global food gap in half.



! Cited as new benchmark for sustainable intensification (MacDonald et al., 2016)

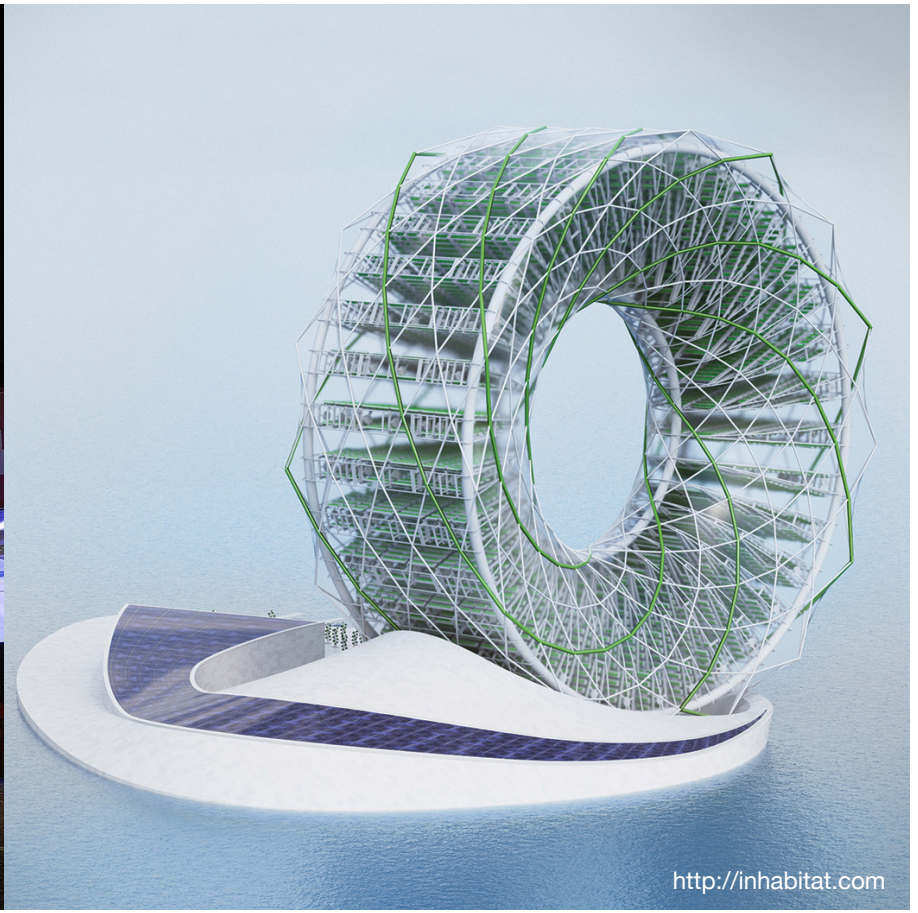
Challenge for human ingenuity



Challenge for human ingenuity

The Growroom -

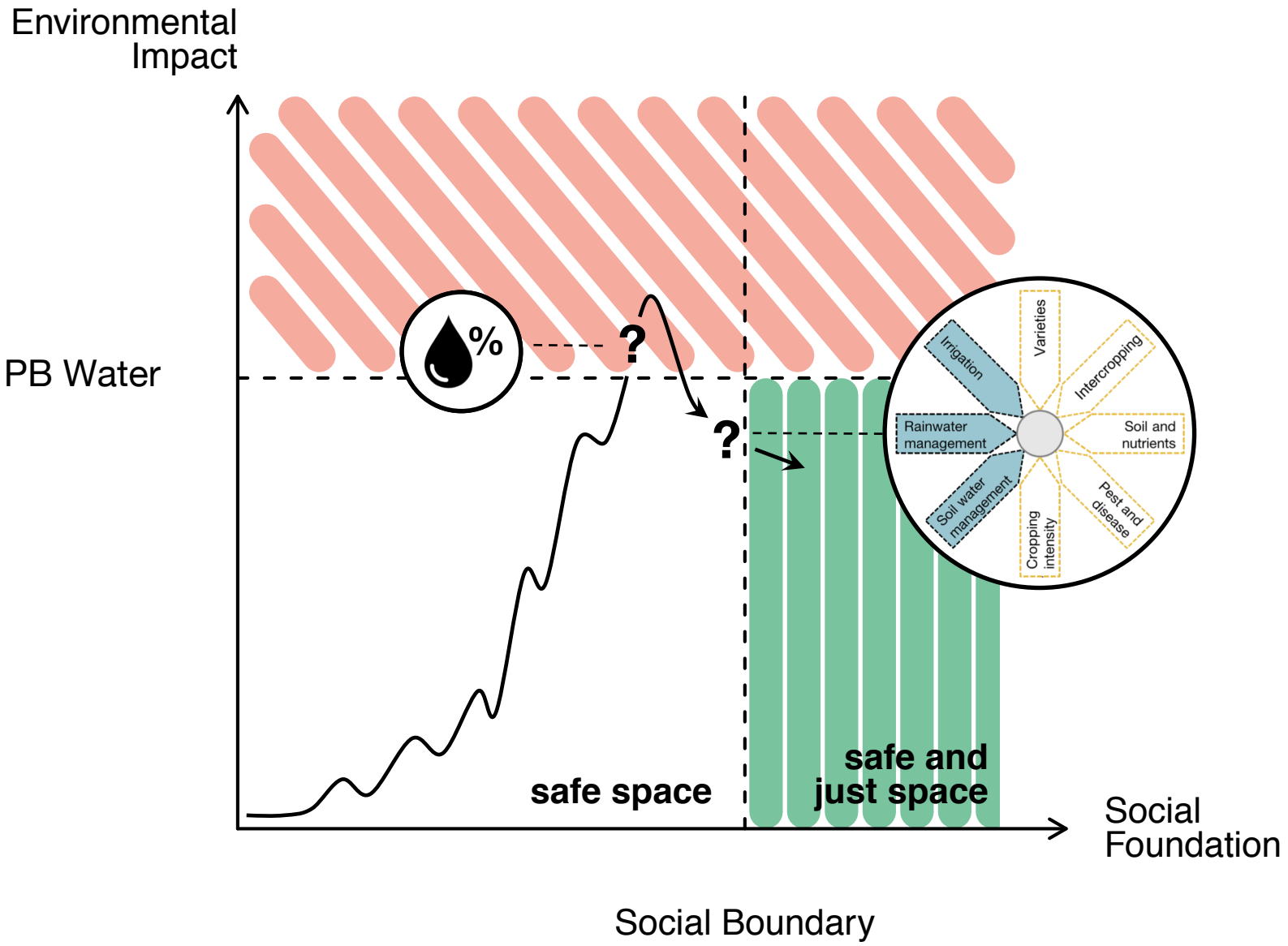
IKEA’s answer to sustainable farming?



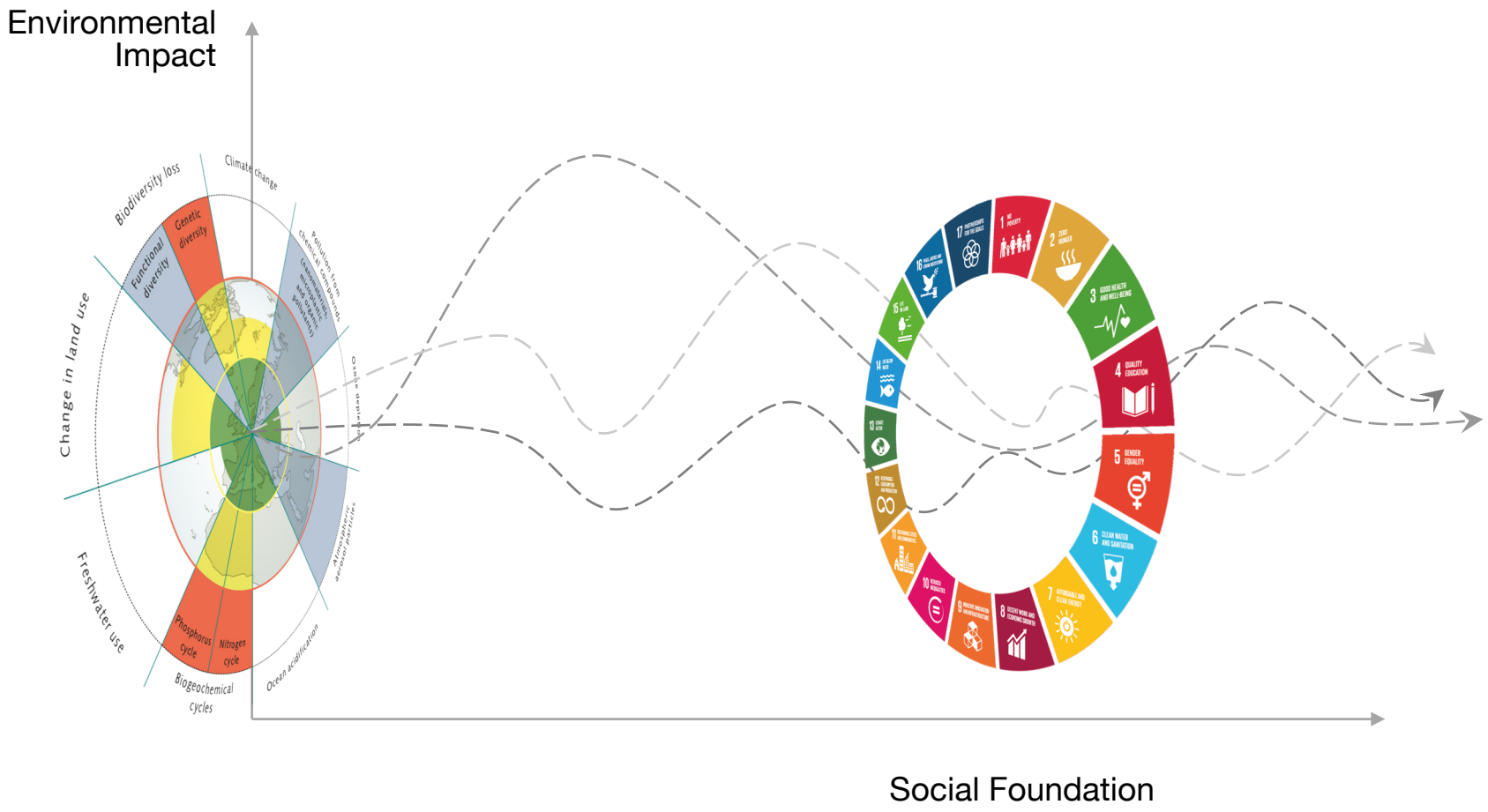
The Ring Garden -

Solar-powered desalination and agriculture plant

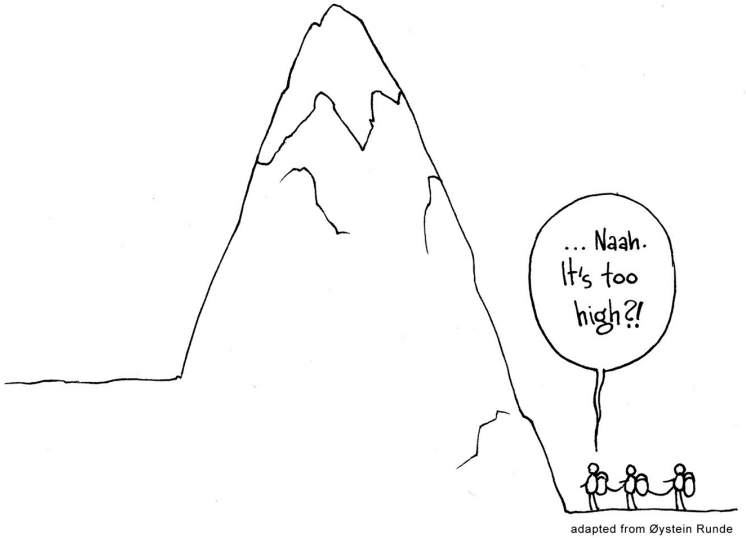
In the first place - an implementation challenge



Outlook


Environmental Impact
Biodiversity loss
Climate change
Genetic diversity
Functional diversity
Change in land use
Freshwater use
Phosphorus Cycle
Nitrogen cycle
Biogeochemical cycles
Ocean acidification
Social Foundation

Thank you.



Related publications

Gerten, D., Heck, V., **Jägermeyr, J.**, Bodirsky, B.L., Fetzer, I., Jalava, M., Kummu, M., Lucht, W., Rockström, J., Schaphoff, S., Schellnhuber, H.J. "Feeding ten billion people is narrowly possible within planetary boundaries" *Submitted*.

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PIK Potsdam Institute for Climate Impact Research

Humboldt-Universität zu Berlin

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